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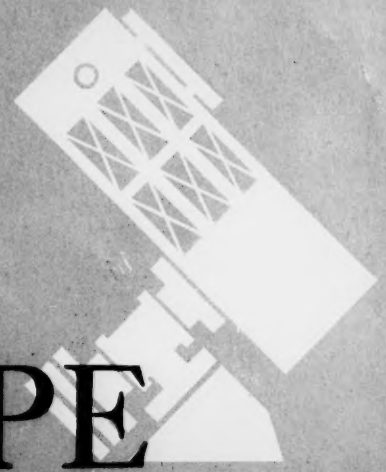

Moon and planets

★

Vol. X, No. 6

APRIL, 1951

Whole Number 114

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In This Issue:

Capella

Halo Photography

The Occultation of Venus

The Source of Energy in the Fainter Stars

Northern and Southern Star Charts

LETTERS

Sir:

Concerning the lunar maps about which Walter H. Haas wrote in your July, 1950, issue (page 206), I purchased Mr. Wilkins' moon map recently and obtained his ideas concerning mounting it.

As it is eight feet four inches in diameter, the map is too large to be conveniently mounted in one piece and hung on a wall. I have assembled the sheets on my living room floor, however, and the map is certainly a stunning object to see. Mr. Wilkins says that, as far as he knows, nobody except himself has ever mounted the map on one sheet. "Most people," he writes, "have their copies on separate linen sheets in a portfolio; one person had mahogany covers and leather backing." Another idea which has come to my attention is to mount the sections on 0.020" aluminum sheet, one on each side, in a homemade ring binder with plywood covers. Rubber cement or Kodak dry mounting tissue could be used and the entire assembly would be permanent, flat, and easy to handle.

Interspersed appropriately with my map sections will be a set of your moon photographs. The two complement each other quite well and the combination should make a highly interesting portfolio.

I agree with Mr. Haas that the map is a most amazing project and its wealth of detail shows the immense amount of labor put forth by Mr. Wilkins.

ARTHUR J. WADSWORTH
Box C-142
Big Tujunga Canyon
Tujunga, Calif.

ED. NOTE: The Wilkins 100-inch moon map may be obtained directly for £2.2.0. postpaid from H. P. Wilkins, 35 Fairlawn Ave., Bexleyheath, Kent, England.

Sir:

In his reply to my criticism of his treatment of the Hoba meteorite (**Sky and Telescope,** January, 1951, page 54), Dr. Wylie contends that on taking the specific gravity of the Hoba shale as half that of the meteorite itself, his formula gives a result for the original weight of Hoba "agreeing within about one per cent" with that given by Spencer. This contention is in error.

Since the specific gravity, 4.021, of Gordon's shale specimen is fundamental to the argument Wylie now presents, he should have relied on Gordon's published analysis of this shale (**Proc.** Acad. Nat. Sci., **83**, 251-255, 1931) in computing its metal equivalent. A calculation of the amount of metal in chemical combination in the shale based on the percentages of Fe_2O_3, FeO, NiO, and CoO given by Gordon shows that instead of adding half a foot of meteorite to the "sides, ends, and bottom" of the present Hoba, as Wylie did in his paper in the November, 1950, issue of **Sky and Telescope,** he should have added only 0.288 feet. But then his formula gives a total weight of only 83 ordinary tons, a result differing by considerably more than one per cent from the 97 tons given by Spencer in his 1932 paper; and in even more serious disagreement with Spencer's present estimate of the original weight of Hoba, which he gives as 100 metric or 110 ordinary tons in a letter written to me on November 19, 1950.

LINCOLN LaPAZ, director
Institute of Meteoritics
University of New Mexico

Sir:

The enclosed list of moon literature (principally moon maps) and other astronomical volumes was sent to me by a woman who wants to sell this part of the estate of her husband, if possible as a whole. She lives in need, and I should be very obliged if you could bring the availability of these valuable books to the notice of your readers. Prices are not given in the list, but they are on the level of the current value of the works. I shall be glad to receive inquiries from genuinely interested persons.

O. HECKMANN, director
Hamburg-Bergedorf Observatory
Hamburg, Germany

ED. NOTE: The list is too long to publish here, but a hectographed copy will be sent by **Sky and Telescope** in return for a stamped self-addressed envelope. As many rare publications are included, the cost of procuring this library is not expected to be small. Address your request for the list to Dept. H, Sky and Telescope, Harvard Observatory, Cambridge 38, Mass.

Sir:

For the past several years, I have made naked-eye daytime observations of Venus, usually at 12:30 p.m. MST, daily, cloud conditions permitting. Durango is 6,500 feet in altitude and skies are usually clear.

The planet was first picked up in 1951 on January 2nd at 3:25 p.m. On the 26th, it was seen at 12:30 p.m.; and on February 11th, at the same hour, Venus and Jupiter were both in the one-degree field of my Argus 20x spotting scope. The disk of Venus was very bright, while the larger disk of Jupiter appeared ghostly.

When Venus is seen near a scudding cloud, the impression is sometimes received that the planet is sailing. This beautiful illusion has been experienced by all who have seen the moon through thin moving clouds.

H. H. PETERSON
140 West 22nd St.
Durango, Colo.

Sky and TELESCOPE

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APRIL, 1951

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COVER: The moon, Jupiter and two satellites, Mars, and an airplane trail (extreme upper left), shortly after the moon had occulted Venus, February 7, 1951. North is at the top. The exposure was 10 seconds, f/6.5, with the 10-inch Cooke asteroid camera at Goethe Link Observatory, University of Indiana. A yellow plexiglas filter caused the bright lines on Venus' image. Emulsion was Eastman 103aG, developed in D19. Photograph by Frank K. Edmondson, Richard C. Nicholas, and Mary L. Connelley. (See page 143.)

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BACK COVER: The Lagoon nebula NGC 6523, Messier 8, in Sagittarius, photographed with the 200-inch Hale telescope on May 15, 1950. The exposure was 10 minutes at full aperture, with the f/3.6 corrector lens, on Eastman 103aE emulsion. The enlargement of the reproduction is about 2½ times. North is at the left. Mount Wilson and Palomar Observatories photograph.

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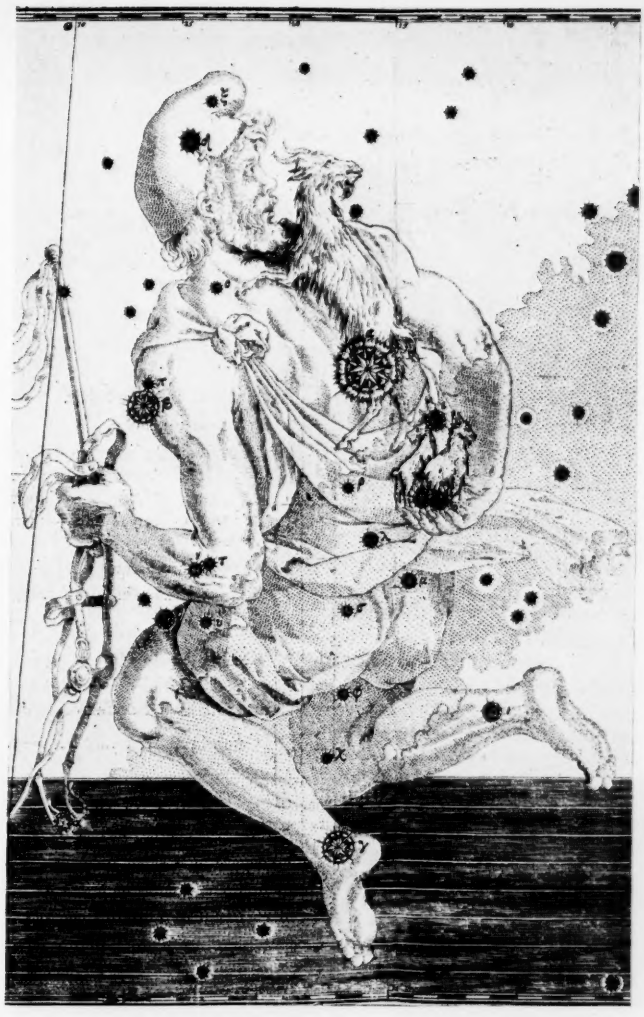
CAPELLA

By Otto Struve

Berkeley Astronomical Department
University of California



In Bayer's "Uranometria," published in 1603, Capella appears as a very brilliant luminary in the constellation of Auriga. It is located in the hindquarters of the she-goat. Note the two Kids that the Charioteer holds in his right hand.

THESE ARTICLES are intended to inform *Sky and Telescope* readers of established facts in astronomy and, sometimes, of progress in current research published elsewhere. But there are occasions when an intelligent reader of necessity becomes a research worker because he can find no answer to a question that has bothered him. It is a matter of this kind that I want to discuss this month.

What do we really know about the second brightest star of the northern sky? The textbooks tell us that Capella is a close binary and that there is a third, distant companion — a red dwarf of apparent magnitude 10 and spectral class *M*, about 12 minutes of arc removed from the bright pair. But what kind of stars are the two components, especially the fainter one? Is it a normal giant like Canopus or Alpha Persei? What is its rotational velocity at the equator and the velocity of turbulence in its atmosphere? And is its spectrum normal, or influenced by streams of gas whirling about the system? Surprisingly, the astronomical literature contains no answers to these simple questions. Hence, we shall have to do some simple research to find out what has not been previously known.

Our tools are the spectra of the stars. The spectra of Procyon and Arcturus, in Fig. 1, were taken with the old coude spectrograph of the McDonald Observatory. Those of Capella (Fig. 4) were obtained with the large coude spectrograph attached to the 100-inch telescope of the Mount Wilson Observatory. In each case the star's spectrum is in the middle, and the white vertical spaces are the absorption lines produced by the atoms in the reversing layer of the star's atmosphere. The heavy black lines belong to the comparison spectrum of iron, impressed at the beginning and end of each exposure. These stars all contain iron, and the reader will notice that for each comparison line there is a corresponding stellar absorption line — slightly shifted by the Doppler effect of the star's motion.

We shall first summarize the established facts. Capella has played an exceptionally important part in the development of theoretical astrophysics. In 1926, A. S. Eddington used it as one of the two anchors to which he attached his famous mass-luminosity relation. The other anchor was the sun. Several other stars were used to bridge the gap between them and to extend the relation at the two ends.

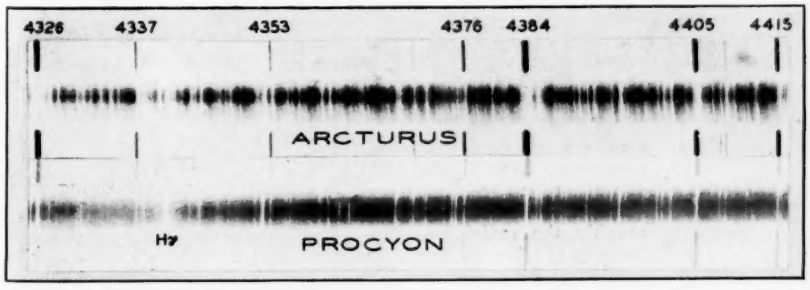


Fig. 1. The spectra of Arcturus and Procyon may be taken as representative of the two components of Capella. McDonald Observatory spectrograms.

Capella was discovered to be a spectroscopic binary in 1899 independently by W. W. Campbell at the Lick Observatory and by H. F. Newall in England. A year later Newall announced that the period was 104 days, and in 1901 H. M. Reese published an accurate orbit based upon the measurements of the Doppler shifts of the spectral lines on 31 spectrograms obtained with the Mills spectrograph of the Lick Observatory. The lines of both component stars were found in the spectra, one corresponding to the solar type and the other being intermediate in character between the solar and the Sirian types. But only the former was easily measurable, and the velocity curve obtained by Reese refers to it. It is evident from his paper that "no very satisfactory determinations of the lesser component's velocities are at hand." While some lines were clearly double, it was difficult to assign the correct line components to the fainter star.

Although this information was important, it would not have sufficed to provide Eddington with the data he re-

quired for fixing the mass-luminosity relation. That additional information came from the work of J. A. Anderson and, especially, P. W. Merrill, at Mount Wilson, who succeeded in observing Capella as a visual double star, using for this purpose the great Michelson interferometer attached to the 100-inch telescope. It was the combination of the visual orbit by Merrill and the spectroscopic orbit by Reese that gave all the necessary data.

The radial velocity of the brighter star varies between +4 and +56 kilometers a second, a range of 52 kilometers per second. The fainter varies between +63 and −3 kilometers per second, a range of 66 kilometers a second. The ratio of the two ranges, or 66/52 = 1.26, is the ratio of the masses of the two stars. The mean velocity, +30 kilometers per second, is the motion of recession of the entire double star with respect to the sun. The eccentricity of the orbit is so small as to be negligible. The orbital speeds, foreshortened by the inclination of 41 degrees to the plane of the sky determined from Merrill's orbit, are equal to one half of the two velocity ranges, or 26 and 33 kilometers per second, respectively. After removing the foreshortening, multiplication of these values by the period of 104 days, expressed in seconds, gives the lengths of the two orbits, which, finally, correspond to radii of 56 million and 71 million kilometers, respectively. The radius of the relative orbit is the sum of these, 127 million kilometers.

The distance of Capella is known with a high degree of precision from the combination of the spectroscopically determined radius of the orbit, in kilometers, and the interferometric measure of the separation of the two stars, in seconds of arc. The result is nearly 16 parsecs, or about 52 light-years.

The masses turn out to be 4.2 and 3.3 solar masses, respectively; and the absolute visual magnitudes are −0.3 and +0.2. The radii of the components are about 10 and eight times the radius of the sun, and the corresponding mean densities are 0.006 and 0.009 grams per cubic centimeter. Both stars are giants.

In recent years, these data have been somewhat revised by W. W. Morgan, who in the Yerkes *Atlas of Stellar Spectra* assigns types *G*5 and *F*6 to the two components. But he remarks that "the separate values for the two components are very uncertain, and may be in error by a considerable fraction of this separation." G. P. Kuiper has used the best modern values of the masses and luminosities for his revision of the mass-luminosity diagram, and has used Morgan's estimate that the photographic magnitudes of the components are nearly the same.

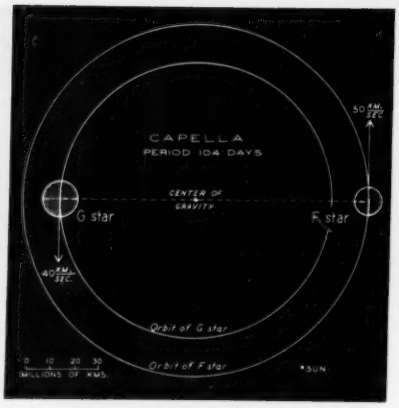


Fig. 2. The component stars of Capella are here drawn to the scale of their orbits around their center of gravity. The orbits are practically circular.

On the radial velocity side, R. F. Sanford, in 1922, confirmed the period of Capella given by Reese, but noted that the second component was difficult to measure. An independent orbit was derived by F. Goos, from measurements of Bonn spectrograms; and in 1938 Wilfried Struve determined a new set of elements with the help of 36 spectrograms obtained at the Berlin-Babelsberg Observatory with the 50-inch reflector and a prism spectrograph giving a dispersion of 8.5 angstroms per millimeter. These orbital elements are similar to those of Reese.

And now let us proceed with our own research. We are told that the spectrum of Capella is composite: one star shines like a late *G*, the other like an *F* star. The two are of about the same brightness, as is shown by the interferometer; in fact, Dr. Merrill, from his work with Capella, told me just recently that in visual (yellow) light the difference between these two stars cannot be greater than a few tenths of a magnitude. We should get a fair approximation if we substitute for the *G* star the spectrum of Arcturus and for the *F* star the spectrum of Procyon (Fig. 1). Or we could have used the sun and Alpha Persei. Both components of Capella are giants, but the differences between giants and dwarfs are not important in this case.

The spectrum of Capella should resemble a superposition of these two spectra, with a small shift either to the right or to the left, amounting to a millimeter in either direction, depending upon which of the two stars is approaching and which is receding. So let us imagine that the *G* star approaches, the *F* star recedes. If we lay the spectrum of Procyon on top of that of Arcturus, shifting it one millimeter toward the right (red) side, the result (not reproduced) will be a hopeless jumble of lines, with many blends, and only a few clearly discernible duplicities. Double lines would, however, be conspicuous in the case of the strong stellar lines corresponding to the comparison lines at wave lengths 4384, 4405, 4415. When the relative motions of the components are reversed, Procyon would be shifted a millimeter to the left of Arcturus (toward the violet). Again there would be a jumble of lines, different from that observed in the first case. And again the strong absorption lines should show conspicuous duplicities.

The jumbled appearance of the composite spectrum is like a coded message; it makes no sense unless we possess a key for decoding it. In our problem there are supposedly two keys: the original and uncomplicated spectra of Arcturus and Procyon. We would simply lay the spectrum of Arcturus along the edge of the composite spectrum of Capella and slide it along a little bit until thousands of faint and many strong lines of Capella coincided with similar lines in Arcturus. We thus would unravel the *G*-type component of Capella. We would next perform the same thing with Procyon, and thus expect to account for all the remaining lines in the composite spectrum.

I have tried to do this using a real spectrum of Capella. The result was that the enormous majority of the lines belong to the *G* star; the agreement with the sun or with Arcturus was almost 100 per cent. But the comparison with Procyon or Alpha Persei yielded nothing definite. It was not possible to match a large number of lines in the composite spectrum of Capella with either *F*-type star, and thus make certain that the companion is really such a star. Clearly, there is something very strange about the spectrum of Capella; otherwise, this second half of the test should have been just as convincing as the first. What is the trouble? Perhaps the companion is much fainter than the primary, so that most of its absorp-

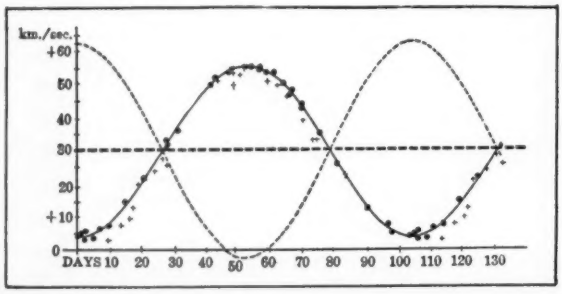


Fig. 3. Capella's radial-velocity curve by H. M. Reese (1901). Lick Observatory measures are plotted as dots; H. F. Newall's as crosses. The dashed curve shows roughly the radial velocities of the F-type star. From Lick Observatory "Bulletin" No. 6, published in 1901.

tion lines are suppressed by the continuous spectrum of the *G* star. This is not probable, however, in view of the interferometer data. More likely the trouble is in the character of the spectral lines of the secondary; perhaps they are so broad and hazy that they do not resemble the sharp lines of the comparison stars.

To find out which explanation is the correct one, I modified the experiment. I obtained two spectrograms of Capella, one with the *G* component approaching, the other with it receding. The velocities were near their maximum values, differing by about 50 kilometers per second, corresponding to a Doppler shift of about 0.7 angstrom at wave length 4200.

We already know that the *G* component predominates. Hence, it is easy to match the lines of this star in the two spectrograms; this involves shifting the comparison lines of the second spectrum to the violet by part of an angstrom. This has been done for the portions of the spectra in Fig. 4, where the lower spectrum (*b*) is shifted about one millimeter with respect to the upper one (*a*). By this means, the *G* spectrum features should have coincident positions in both *a* and *b*, whereas the *F* spectrum should be shifted to the right (red) in *a* and to the left in *b*, the total shift being about twice the difference between the spectra.

Except for some small systematic differences (due to differences in the dispersing properties of the spectrograph when the two plates were obtained), nearly all the faint lines and many strong lines coincide in position. This, once more, confirms our conclusion that nearly everything we see in the spectrum of Capella comes from one star, the *G*-type component. But, in addition, there are a few very strong and broad features that do not coincide; these are the lines of the *F* component.

Consider the line of Fe I 4045.8. On the upper spectrum, there is an amazingly broad and deep absorption line about one millimeter to the right of the comparison line. There is no such feature in the same position below, although all the faint lines nearby do coincide. Instead, a broad hazy absorption appears in the lower spectrum, to the violet of the comparison line, where it should be if it is produced in the *F* star. The total shift of this line is about 90 kilometers per second between the two exposures — somewhat less than expected from Reese's orbit for the *F* star.

Where is the 4045 line of the *G* star? It should be shifted about ¼ millimeter to the right of the upper comparison line and one millimeter to the right of the lower comparison line, and it should be stronger than any of the other *G*-type lines nearby. Yet, it is not visible! On the upper plate it may be lost in the strong left wing of the 4045 line of the *F* star. But on the lower plate we should have expected to see it.

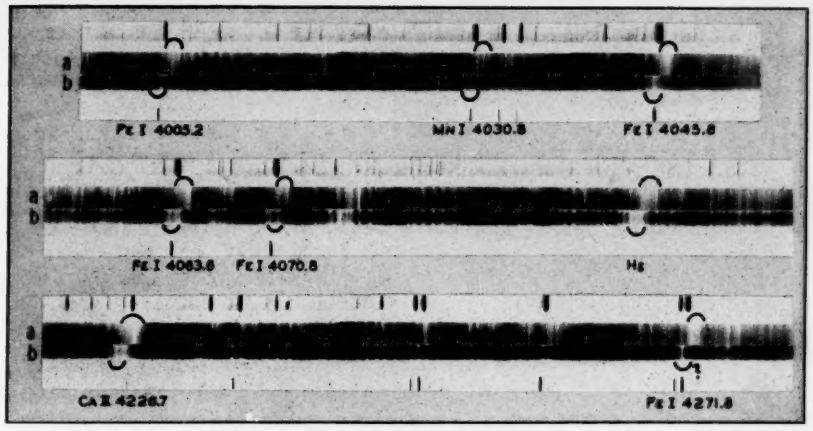


Fig. 4. Two spectra of Capella, taken with the coude spectrograph of the 100-inch reflector at Mount Wilson Observatory, one on November 15, 1940, by Theodore H. Dunham, Jr., the other on December 31, 1950, by the author. The reproduction scale is about ½ angstrom per millimeter. Although representing times when the component stars showed nearly maximum differences in radial velocity, the spectra are not shifted a corresponding amount because of the effect of the earth's orbital motion, which differed for Capella on the above dates. These and the spectra of Fig. 1 are negative reproductions, so the stars' absorption lines appear bright against the darker continuous spectrum. Mount Wilson Observatory photographs.

This same effect is visible in nearly all the very strong absorption lines — those which are normally strong in both spectral types, *G* and *F*. In some there is an indication of duplicity, such as we had anticipated at the outset, but always these duplicities are heavily blended with lines of the *G* star. The lines of the *F* star are, as a rule, diffuse and broad. There is often a well-marked condensation — like a core of absorption — within a broad and diffuse haze that extends over the entire interval between the two double components.

The strongest *F*-type lines, for example λ4045, are much stronger than the corresponding lines of the *G* star. Thus, we cannot simply assume that the *F* star is fainter than the *G* star. On the contrary, the two stars are probably similar in brightness, just as the interferometer had shown.

But the *F* component is not a normal giant. It has spectral lines that are greatly broadened by turbulent motions in its atmosphere. Experience has shown that such motions tend to make the normally strong lines intensely deep and broad, surpassing in this respect the lines of all dwarfs and most giants. On the other hand, these same motions obliterate the fainter absorption lines. This, then, explains why only the strongest lines of the *F* component in Capella are visible as broad and strong features, while all the faint lines that are normally present in an *F* star are absent.

It is not possible, at present, to give an estimate of the velocities of the turbulent motions, but they are perhaps as large as in any star yet observed. Nor can we be sure that this explanation suffices for all the observed peculiarities. There are real differences between the *F* lines in the two spectra which cannot be explained by the blending with lines of the *G* star. For example, in spectrum *a* the strong absorption feature at Fe I 4271 is a broad, deep line about one millimeter to the right of the stronger of the two comparison lines. There is no such feature on the bottom plate. Hence, we are dealing with an absorption line of the *F* star. We would expect to find it shifted somewhat to the left in the lower spectrogram. But there is only the barest trace of a broad hazy feature, nothing like the strong band at the top.

We could go on and on, listing the unusual features of the *F* star. But that is the task of a specialist. For us it is enough to have found that the *F* star is not the simple kind of object astronomers had thought it was. Despite the fact that its distance from the *G* star is so large that we should not have suspected the existence of pronounced peculiarities, it does not resemble any known single star, and it may be subject to large changes of a kind we have not found elsewhere in the universe.

Next time you happen to be outdoors on a clear, moonless night, try to locate the constellation Auriga, and within it the configuration formed by Capella, Zeta Aurigae, and Epsilon Aurigae. All three are famous binaries. Of the thousands listed in our catalogues, they are perhaps the most remarkable objects in the sky. But the stories of Zeta and Epsilon Aurigae must be postponed until some other time.

THE SOURCE OF ENERGY IN THE FAINTER STARS

By Lawrence H. Aller, *University of Michigan Observatory*

IT HAS long been recognized that the stars must derive their energy from nuclear transformations. Other sources of energy, such as oxidation, contraction, and the impact of meteors, are all woefully inadequate; either they fail to deliver energy at the correct rate or they give an age to the sun (in particular) which is not in accordance with geological evidence.

Considerable attention has been devoted to the exact mechanism by which energy is generated in the stars. The basic idea is a very simple one. If matter can be converted into energy, the amount of energy obtained will be $E = mc^2$. (If c, the velocity of light, is measured in centimeters per second, and m is measured in grams, E will be in ergs.)

The simplest assumption was that, by some unspecified process, matter was simply annihilated, that is, completely converted into energy. According to this idea, a star could start its life as a massive B star and just migrate down the main sequence as it converted its mass into energy. Unfortunately for this hypothesis, modern physics does not permit such a total conversion of mass into energy, and we must look for some mechanism supported at least in part by the evidence of experimental nuclear physics.

The radioactive disintegration of uranium into radium and ultimately into lead is an example of the conversion of mass into energy. The unstable heavy uranium nucleus gradually breaks down until it ends up as the stable nucleus of lead, and in the course of development considerable energy is liberated. Although a sun composed entirely of known radioactive materials would not shine brightly enough, a fainter star might be accounted for in this fashion. The radioactive elements, however, are very rare on the earth, and it seems improbable that they are more abundant in the sun or other stars.

Thus we are faced with the necessity of using some abundant element or elements to provide the power output of the stars. One suggestion is that hydrogen is converted into helium. Hydrogen has an atomic weight of 1.00813, whereas that of helium is 4.00386. Hence, if four hydrogen atoms could be converted into one helium atom, 0.02866 atomic units of mass, or 0.7 per cent of the original mass, would be converted into energy in accordance with Einstein's relation. This process seems to be the actual source of stellar energy, but the mechanism is not so simple as squeezing four protons together to form a helium nucleus.

The best-known process by which hydrogen is converted into helium is the celebrated carbon cycle, wherein carbon acts as a catalyst. This process was independently suggested in 1938 by Hans Bethe and C. F. von Weizsaecker. Another process, suggested by Bethe and Critchfield, may be more important for the fainter stars of the main sequence, and even for the sun. This is the proton-proton reaction, which proceeds without the aid of a catalyst such as carbon.

The first (and at higher temperatures the most difficult) step in the process is the jamming together of two protons to form a deuteron — the nucleus of a heavy hydrogen atom. A deuteron consists of a proton and a neutron bound tightly together. The neutron has very nearly the same mass as the proton (1.66×10^{-24} gram), but it carries no charge. Hence, in the formation of a deuteron by the combination of two protons, each of which carries unit positive charge, one excess positive charge must be carried away. At the same time as the deuteron is formed, a positive electron or positron is created which carries a unit positive charge. Thus we write the fundamental step in the proton-proton reaction as formula A in Fig. 2.

Now the probability of the formation of a deuteron in this fashion is very low indeed. Each proton carries a positive charge, so they repel one another. Only when the collision is head on is there a chance for a deuteron to be formed, and then only if a positron is created simultaneously. In the interior of a star like the sun a given proton is likely to last thousands of millions of years before it forms a deuteron, even though it suffers encounters with other protons millions of times a second!

The deuteron, once formed, enjoys but a short life. It readily captures another proton to form the light isotope of helium, as in formula B. What happens next? It was originally thought that the light isotope of helium would collide with a nucleus of ordinary

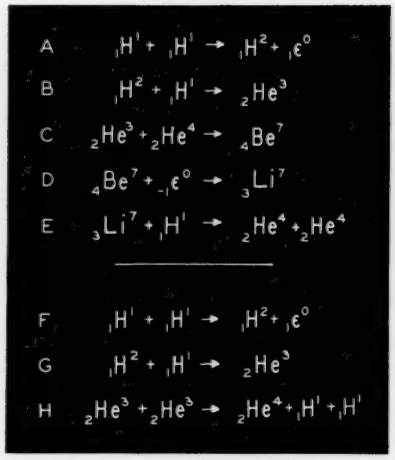

A $_1H^1 + _1H^1 \rightarrow _1H^2 + _1\epsilon^0$
B $_1H^2 + _1H^1 \rightarrow _2He^3$
C $_2He^3 + _2He^4 \rightarrow _4Be^7$
D $_4Be^7 + _{-1}\epsilon^0 \rightarrow _3Li^7$
E $_3Li^7 + _1H^1 \rightarrow _2He^4 + _2He^4$
F $_1H^1 + _1H^1 \rightarrow _1H^2 + _1\epsilon^0$
G $_1H^2 + _1H^1 \rightarrow _2He^3$
H $_2He^3 + _2He^3 \rightarrow _2He^4 + _1H^1 + _1H^1$

Fig. 2. The series of nuclear reactions of the hydrogen-beryllium-lithium process of energy generation (A to E), and the hydrogen-helium-light-isotope process (F to H), now considered more important, by which dwarf stars may produce energy. The subscript represents the electric charge of the particle, which is also the atomic number of the element. The superscript gives the mass or the atomic weight to the nearest whole number.

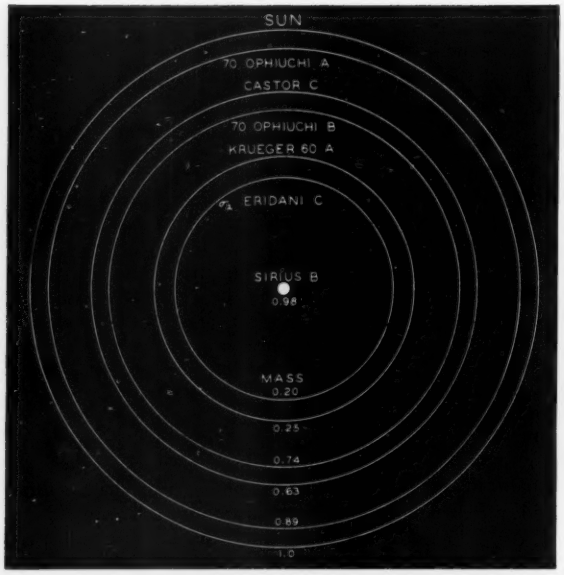


Fig. 1. The sun and some typical dwarf stars drawn to scale. Their masses in terms of the sun's are shown. Their densities average about twice the sun's, except for the white dwarf companion of Sirius (for which the energy generation must also differ). Their spectral types are G for the sun, K1 and K5 for 70 Ophiuchi A and B, M1e for Castor C, M4 for Krueger 60 A, M4e for σ_2 Eridani C, and A7 for the companion of Sirius.

helium, an alpha particle, to form beryllium of atomic weight 7. The beryllium nucleus would then capture a negative (ordinary) electron to form lithium of atomic weight 7. The lithium nucleus finally would capture a proton and break down into two alpha particles or helium nuclei, as shown by the formulae, C, D, and E, in Fig. 2.

Very recently, Fowler and Lauritsen have demonstrated that the reaction of the light isotopes of helium with each other is more important than the lithium-building reactions, even though He^3 is much less abundant than He^4. This "simplifies" the proton-proton "cycle" to the three steps shown in formulae F, G, and H, in Fig. 2. As a consequence, however, two deuterons must be formed for every helium nucleus created, and the rate of energy generation is half of what would be given by the process involving lithium of atomic weight 7.

The time required for a helium nucleus to be formed is very long. At a temperature of 15,000,000° absolute, a density of 80 grams per cubic centimeter, and with a hydrogen content of a third by weight, it requires 500 million years. The dependence on the temperature is not nearly so steep as for the carbon cycle. The rate of energy generation by the carbon cycle varies as about T^{20} at 17 to 20 million degrees, whereas it varies only as T^4 for the proton-proton reaction.

One important point must be mentioned. The essential steps in the carbon cycle all have been checked in the laboratory. On the other hand, no direct experimental verification of the first step in the proton-proton reaction can be made. To estimate the rate of this process we must rely on theories of nuclear structure. These processes seem well enough understood to justify our confidence in the theoretical predictions.

The investigation of stellar interiors must be carried out entirely by theoretical methods. The observations tell us, under favorable circumstances, the luminosity, mass, and radius of a star. These are what the mathematician calls the boundary conditions of the problem. Given the condition that the star is in equilibrium, neither swelling up nor shrinking down, and a knowledge of its chemical composition, we can calculate the structure or *model* of the star. It is found that it is not possible to fit the observed boundary conditions with any choice of composition. In fact, the hydrogen content (X) and the helium content (Y) may be determined, provided we know the relative abundances of the heavier elements, carbon, nitrogen, oxygen, and so forth, and the metals.

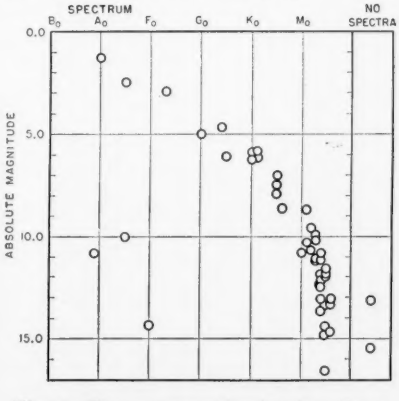


Fig. 3. The spectrum-luminosity chart for stars nearer than five parsecs, indicating the abundance in space of stars fainter and redder than the sun, which is at absolute magnitude 5, spectrum G0. A few white dwarfs are at the left. Sproul Observatory diagram.

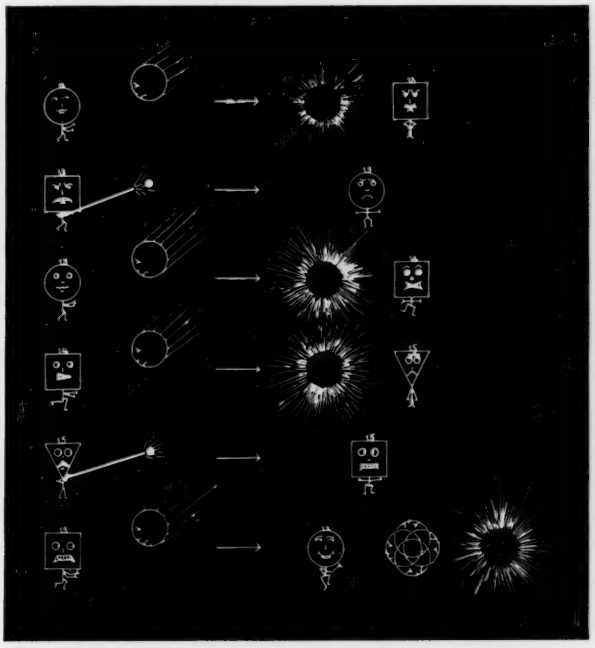


Fig. 4. The six acts of the carbon cycle, as conceived in personified elements by Dr. Cecilia Payne-Gaposchkin. At the beginning, an atom of carbon 12 is struck by a hydrogen nucleus (proton), to emit gamma-ray energy and turn into nitrogen 13. This unstable atom emits a positron to become carbon 13, which is struck by another proton (Act 3). The resulting nitrogen 14 is again bombarded by a proton, becoming unstable oxygen 15. This turns back to nitrogen 15. The final bombardment produces the original (smiling) carbon again, a helium nucleus, and more radiation.

All of this presupposes that we know the law of energy generation, its dependence on temperature, density, and chemical composition; and also the law of opacity, which determines the rate at which energy flows through the material in the regions of the star where radiation (rather than large-scale mass motions of heated gases) carries the energy. The quantities are now sufficiently well known to permit a reasonable estimate of conditions in stellar interiors.

The analysis gives two simultaneous equations which involve the hydrogen and helium contents and the luminosity, mass, and radius of the star. The first equation amounts to the so-called mass-luminosity law, whereas the second equation involves the rate of energy generation. We can lay no claim to accuracy for a solution, as we have assumed that the same opacity law holds as for the sun. Since a red dwarf is a much denser star than the sun, the dependence of the opacity on density and temperature necessarily will be a little different and our results can be of only qualitative significance.

Now, the solution will depend on the assumed law of energy generation. We may suppose that only proton-proton reactions take place. Then we obtain for σ_2 Eridani C a central temperature of 13,000,000° K. The other assumption is that both the carbon cycle and proton-proton reactions hold. Then the central temperature is 15,000,000°. Both of these solutions "represent" the star within the framework of the theory, but the mechanism actually followed will depend on the hydrogen and helium contents. At 13,000,000° the carbon cycle is unimportant. In the same way, we find the red dwarf Krueger 60 A could have a central temperature of 15,400,000° and operate on both the carbon and proton-proton cycles, or a central temperature of about 10,700,000° purely on the proton-proton cycle.

These results are to be regarded as qualitative only. First, as noted previously, since this article was prepared it has been found that the proton-proton reaction proceeds half as fast as formerly supposed. Second, if the energy generation is due to the proton-proton reaction, it must occur throughout large portions of the stellar interior and not near the core, as supposed in these models. Third, the law of opacity needs revision.

Furthermore, we have supposed that the heavier constituents comprise a large fraction of iron and other metals — the so-called Russell mixture. Recent work, however, indicates that the elements such as oxygen, carbon, nitrogen, neon, silicon, are far more abundant than the metals.

The hydrogen contents seem too low

and the helium contents too high as compared with the chemical make-up of normal stellar atmospheres. The discrepancies are probably to be attributed to the approximations in the models. Calculations at present in progress, which take into account the energy generation throughout the entire star, may resolve some of these difficulties.

Theoretical luminosity-mass and radius-mass plots by Gamow and Critchfield and a theoretical Russell diagram by J. B. Oke tend to favor the carbon cycle for stars of the main sequence, but the models upon which these conclusions are based are subject to revision.

The proton-proton reaction is an extremely slow one which could have no terrestrial application. Reactions involving the heavy isotopes of hydrogen — deuterium and tritium — are a different matter. The deuterium nucleus or deuteron consists of one proton and one neutron. The nucleus of tritium consists of one proton and two neutrons, $_1H^3$.

First, if two deuterons were jammed together there would result either the formation of a nucleus of tritium plus a proton, and about 15 per cent as much energy as is released in the carbon cycle, or the formation of helium of atomic weight 3, a neutron, and the release of about the same amount of energy.

A second possible reaction would involve deuterium and tritium when these two nuclei of the heavy hydrogens collide. The resultant reaction leaves an alpha particle and a neutron, and a gamma ray is emitted.

The amount of energy released would be about 65 per cent as much as is released in the carbon cycle, but whereas it takes a million years for four protons to be converted into one helium atom in the sun, the above hydrogen reactions take place in a millionth of a second — releasing the energy all at once. The nuclear reactions involving uranium and plutonium can be made to take place slowly — as in an atomic pile. There the formation of isotopes and the release of energy proceed in an orderly fashion and can provide a source of power. The hydrogen reaction, however, can be utilized only for explosions, since the reaction does not perpetuate itself.

Furthermore, the heavy hydrogen reactions can take place only if the energies of the interacting particles are sufficiently high. In the laboratory, the requisite energies are attained for a few particles by means of a cyclotron or electrostatic generator. In order to make the reactions deliver energy on a large scale, it is necessary to produce a high temperature even if only for an instant, since the reaction takes place very rapidly. If an ordinary U235 or plutonium atomic bomb is used as a detonator, the necessary high temperature will be achieved for the short instant required for the heavy hydrogen reaction.

Whereas the size and destructiveness of the original atomic bomb are limited by the condition that the total mass involved cannot be many times a certain critical mass, the size and destructiveness of the H-bomb are limited only by the ingenuity of its designers and the necessity of delivering it to its target. Discussions have been based on the idea of a bomb a thousand times as destructive as the original atomic bomb. Nevertheless, such a lethal contraption would be a most insignificant spark were it placed on or within even the faintest of the red dwarf stars. The prodigious energy production of the stars is almost beyond conception from human experience.

Planetarium Notes

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 2370.
SCHEDULE: 4 p.m. Monday, Wednesday, and Friday; Thursday evening, 7:45, 8:30, 9:30 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BOSTON: *Little Planetarium.* Boston Museum of Science, Science Park, Boston 14, Mass. Richmond 2-1410.
SCHEDULE: Tuesday thru Friday at 3:30 p.m.; Saturday, 11 a.m., 2, 3, and 4 p.m.; Sunday, 2, 3, and 4 p.m. Spitz projector. In charge, Charles A. Federer, Jr.

BUFFALO: *Buffalo Museum of Science Planetarium.* Humboldt Parkway, Buffalo, N. Y., GR-4100.
SCHEDULE: Sundays, 2:00 to 5:30 p.m. Admission free. Spitz projector. For special lectures address Elsworth Jaeger, director of education.

CHAPEL HILL: *Morehead Planetarium.* University of North Carolina, Chapel Hill, N.C.
SCHEDULE: Daily at 8:30 p.m.; Saturday and Sunday at 3:00 p.m. Zeiss projector. Director, Roy K. Marshall.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Drive, Chicago 5, Ill., Wabash 1428.
SCHEDULE: Mondays through Saturdays, 11 a.m. and 3 p.m.; Sundays, 2:30 and 3:30 p.m. Zeiss projector. Director, Wagner Schlesinger.

KANSAS CITY: *Kansas City Museum Planetarium.* 3218 Gladstone Blvd., Kansas City 1, Mo., Chestnut 2215.
SCHEDULE: Wednesday and Saturday, 3:30 p.m.; Sunday, 3:00 and 5:00 p.m. Spitz projector. Director, Charles G. Wilder.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 9787, Los Feliz Station, Los Angeles 27, Calif., Olympia 1191.
SCHEDULE: Wednesday and Thursday at 8:30 p.m.; Friday, Saturday, and Sunday at 3 and 8:30 p.m.; extra show on Sunday at 4:15 p.m. Zeiss projector. Director, Dinsmore Alter.

NEW YORK CITY: *Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Endicott 2-8500.
SCHEDULE: Mondays through Fridays, 2, 3:30, and 8:30 p.m.; Saturdays, 11 a.m., 2, 3, 4, 5, and 8:30 p.m.; Sundays and holidays, 2, 3, 4, 5, and 8:30 p.m.; Wednesdays and Fridays, 11 a.m., for school groups. Zeiss projector. Chairman, Robert R. Coles.

PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.
SCHEDULE: Tuesdays through Sundays, 3 p.m.; Saturdays, 11 a.m.; Saturdays, Sundays, and holidays, 2 p.m.; Wednesdays, Fridays, and Saturdays, 8:30 p.m. Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 4300.
SCHEDULE: Mondays through Saturdays, 2:15 and 8:30 p.m.; Sundays and holidays, 2:15, 3:15 and 8:30 p.m. Zeiss projector. Director, Arthur L. Draper.

PORTLAND, ORE.: *Oregon Museum of Science and Industry Planetarium.* 908 N.E. Hassalo St., Portland 12, Ore., East 3807.
SCHEDULE: Saturday, Sunday, and Wednesday, 4:00 p.m.; Tuesday, Thursday, and Friday, 8:00 p.m.; Saturday show for children only, 10:30 a.m. Spitz projector. Director, Stanley H. Shirk.

SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.
SCHEDULE: Tuesdays, Thursdays, and Saturdays at 3 p.m.; Tuesday evenings at 8 p.m.; special star stories for children on Saturdays at 2 p.m. Admission free. Korkosz projector. Director, Frank D. Korkosz.

STAMFORD: *Stamford Museum Planetarium.* Courtland Park, Stamford, Conn.
SCHEDULE: Sunday, 4:15 p.m. Special showings on request. Admission free. Spitz projector. Director, Robert E. Cox.

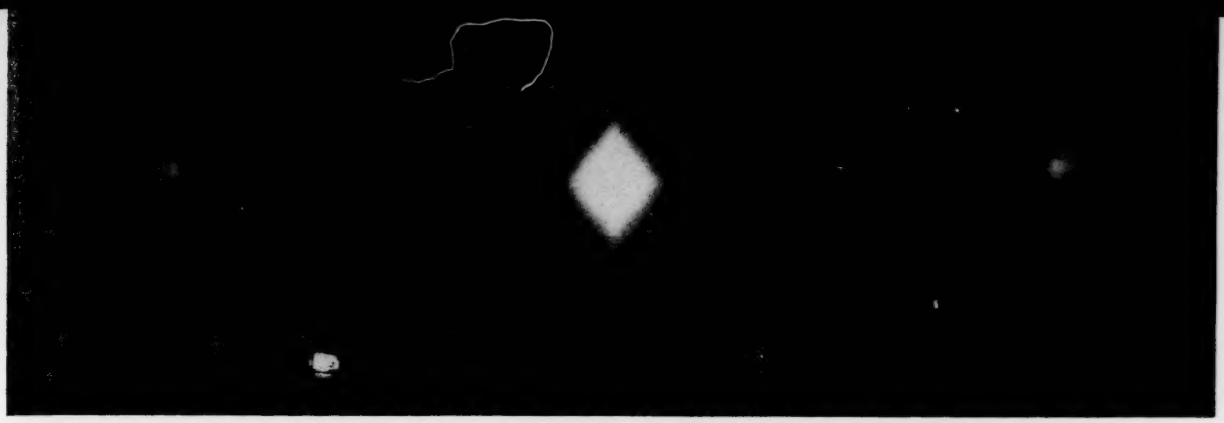
UNUSUAL BLUE STAR

One of the bluest objects in the sky, the star BD +28°4211, is located, unlike most hot stars, at relatively high galactic latitude (20°). It is closer to us than 1,000 parsecs, for its spectrum contains no interstellar calcium lines. This and other peculiarities were described at the Cleveland meeting of the American Association for the Advancement of Science by Donald A. MacRae, Case Institute of Technology, Robert Fleischer, Rensselaer Polytechnic Institute, and Edwin B. Weston, University of Michigan.

Most bright blue stars have narrow spectral lines, whereas this star's hydrogen lines are broad and diffuse, and there are no emission lines. The star is believed to lie several magnitudes below the main sequence on the Russell-Hertzsprung diagram, but its exact location requires additional observations.

SOLAR ENERGY FOR MAN

Were we to consume our natural fuel resources at the same rate as that at which the earth intercepts energy from the sun, our entire supply would be used up in just three days. Less than an hour at the same rate would exhaust the known nuclear fuels. Dr. George O. G. Loef, director of the Institute of Industrial Research at the University of Denver, predicts that within the next decade or so electricity will be generated from the sun's power, Science Service reports.



The moon and mock moons above are made up of composite pictures. At the left below, the sun is hidden behind a building, at the center of a 22-degree halo. At the right below is a 120-degree countersun and part of the horizontal circle.

Halo Photography

FIVE YEARS AGO I was fortunate enough to witness an almost complete lunar halo display. During the last part of January and early in February this year, we in this part of the country have again seen both the sun and the moon playing tricks, extreme enough to cause radio comment and widespread interest. This time I was in a position to attempt photographs. Unfortunately, the film does not begin to register all that was visible. One does not get a lot of experience at this sort of thing. Yet I learned enough so that I believe quite a faithful rendering can be achieved with the proper exposures.

Pictures of this type, though not perhaps so valuable scientifically, are fun to make, and they do cause some eyes to pop. And there is good photographic experience in seeing what one can get to register on a film and show in a print. In general, we amateur astronomers do not use our cameras enough.

An exposure meter is useless on the moon. To get halo pictures, use a tripod, and expose three, five, and 10 seconds (perhaps even longer), taking pairs of pictures, right and left, with the moon on each. This way one can make a composite of the whole 22-degree halo. The moon will move somewhat, and be hopelessly overexposed, but we are after the halo and horizontal circle, if any, and the cross-arms of light from the moon. The light from these adjuncts is very feeble. Use the fastest panchromatic film you can get, and be sure to allow full development. I used Kodak Super-Panchro Press, three seconds at f/5.6, which was not enough to register the whole halo.

Include some horizon material to orient the picture. If you have to shoot high, get near a tree, high building, or a telephone pole, to attach your picture to the ground. If you don't, people will say, "We give up. What is it?"

For the sun, I used Kodak Super-XX, and a red "A" filter. It was about 4:00 p.m. when the solar halo pictures were taken, and the meter indicated 1/100 second at f/11. So I opened up to f/8, which wasn't a bit too much for this time of day. If I had it to do over again, had more time, and wasn't freezing to death, I would take a meter reading for one pair of pictures, and then take a pair opening up one, two, or even three stops, or else change shutter speeds to achieve the same result. However, one has to be careful about the shutter when it is cold (it was −10° when I was working), and the safest policy is to leave the shutter speed alone on your pet camera.

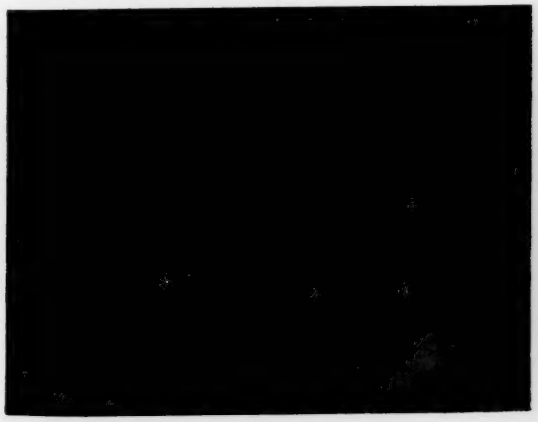
I took pictures without the filter, also, but had the best results with it, although of course it darkens the sky abnormally. As in cloud photography, if you want detail, use filters.

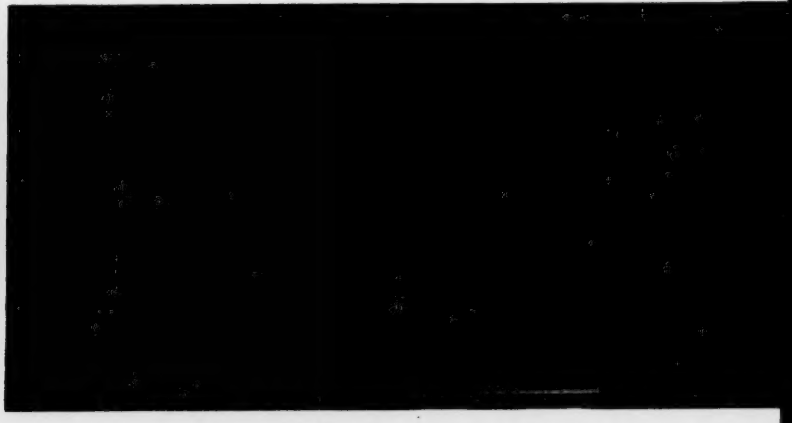
The composite picture is of the moon, taken January 24th, three-second exposure at f/5.6; the inner halo was complete, but did not register all around with this short exposure. The mock moons were strongly colored, an unusual event. The horizontal circle was present to about 20 degrees right and left of the moon; also the vertical part of the "cross" on the moon extended nearly to the 22-degree halo.

On January 27th, the sun had a 22-degree halo, with its bow at the top, and the 46-degree halo was sometimes present, with an intense circumzenithal bow. I have never seen it so bright. The picture with the sun behind a building registers a quadrant of the 22-degree halo, and shows its bow above.

The picture with the pole at the left was the one I am really fortunate to have gotten, although it does not do justice to the horizontal circle. This picture is taken toward the northwest, and one can trace the horizontal circle and see the 120-degree additional countersun near the right side of the picture. This was a white patch, actually about twice the size of what registered on the film.

THEO. SKONNARD
120 Fourth St. North
Fargo, N. D.





Amateur Astronomers

Astronomical League General Convention in North Carolina

An annular eclipse and a Zeiss planetarium are the two special features offered those planning to attend the 1951 Astronomical League convention in Chapel Hill, N. C., September 1-3, 1951. Other special activities include an indoor meteor hunt and a variable star chase.

Though near the southern edge of the eclipse path, Chapel Hill will have an annular phase of 38 seconds duration, occurring 10 minutes after sunrise. Those attending the convention may wish to plan to arrive sometime Friday, August 31st, to be in good trim for the pre-sunrise transfer to the eclipse observing site nearby. By midmorning Saturday, eclipse observers from near and far will gather at the formal convention opening. In the afternoon an eclipse and solar forum, lunar and planetary demonstrations, and an instruments session are scheduled. A banquet and a lecture will be held early Saturday evening.

After a free morning Sunday, there will be sessions on observing; that evening, program planning and meteor work will be discussed, followed by observing outdoors.

Simulated meteor and variable star observing in the Morehead Planetarium will close the convention, which ends at noon on Labor Day.

Dr. Roy K. Marshall, director of the Morehead Planetarium, University of North Carolina, extended the invitation to the league to hold its convention at Chapel Hill. Also participating will be Dr. Douglas Duke, assistant director of the planetarium.

A large room in the planetarium will be set aside for exhibits and registration. This year, commercial exhibitors will have an opportunity to take part, but since all space is free of charge, league members will have preferential consideration. There will be no prizes, but many ideas to take home.

Persons attending the convention will be accommodated in the dormitories on the university campus at a cost of $2.75 per night for a single room, $4.00 for a double. Meals may be secured at a cafeteria, in the Carolina Inn dining room, or at several other eating places, all within four blocks of the planetarium.

Several societies are co-operating on convention arrangements under the chairmanship of G. R. Wright, of Washington, D. C., chairman of the Middle East region. Assisting him are P. N. Anderson and Elizabeth Fazekas, Norfolk, Va.; Mrs. Z. V. Conyers, Greensboro, N. C.; Richard C. Davis, Raleigh, N. C.; Janet Perkins, Grace Scholz, and Mabel Sterns, of Washington, D. C.; and Lillian Sievers and T. W. Stone, Richmond, Va.

NORTHEAST CONVENTION

On APRIL 28th and 29th, Saturday and Sunday, the Northeast region of the Astronomical League will meet in Springfield, Mass., at the Museum of Natural History, for its annual convention. Registration will begin at 10 o'clock Saturday, preceded by a regional council meeting, and followed by the opening session at 10:30. The roll call of societies will be presided over by the regional chairman, Paul W. Stevens. After the group photograph at noon, there will be a smorgasbord luncheon.

At 2:00 p.m., Drs. Warren K. Green and Albert P. Linnell, of Amherst College, will give demonstrations of photometric measurements and equipment. Then the 1951 convention of the league will be discussed, the annular eclipse of September 1st, and general eclipse observing. At 3:45 p.m., Frank Korkosz, of the museum staff, will speak about the design and building of the Korkosz projector and will demonstrate it in the Seymour Planetarium.

If the evening is good from the weather standpoint, the delegates can look forward to an inspection of Amherst College Observatory and observing with its 18-inch refractor. In case of cloudy weather, there will be an alternate program of motion pictures. The expedition to Amherst will leave Springfield in time to have dinner in the town of Amherst.

Sunday morning events open with a regional council meeting at 8:30, followed by a session on instrument making. The discussion will include the parabolizing of mirrors, the Maksutov telescope, instruments for solar observing, and abrasives. At the succeeding session, with Clinton Ford presiding, the observing of variable stars will be discussed, also the planning of astronomical club programs and of observing programs, and occultation work. The final business session will be at noon, to be adjourned at 12:45.

As with all conventions of the Astronomical League, interested persons may attend any or all of the sessions. Societies are requested to notify the undersigned by April 14th how many in their group expect to attend. Advance registrations at $1.00 per person may be mailed to Warren I. Fillmore, 1321 Plumtree Rd., Springfield, Mass. Papers not exceeding 10 minutes reading time should be sent not later than April 1st to Rolland LaPelle, 54 Fernleaf Ave., Longmeadow 6, Mass.

Overnight accommodations are the responsibility of individuals attending the convention, but hotel information may be had from your local society if it is within the Northeast region, or from the writer.

JOHN E. WELCH, chairman
Springfield Stars Club
107 Lower Beverly Hills
West Springfield, Mass.

THIS MONTH'S MEETINGS

Cambridge, Mass.: The Bond Astronomical Club will hold its annual dinner on Thursday evening, April 5th, at the Bella Vista restaurant.

Cleveland, Ohio: "Beacons of the Milky Way" will be discussed by Dr. Helen Sawyer Hogg, of the David Dunlap Observatory, at the April 27th meeting of the Cleveland Astronomical Society, 8:00 p.m. in the Warner and Swasey Observatory.

Dallas, Tex.: The Texas Astronomical Society will hear J. O. Newberry speak on "Stars: Magnitudes and Distances," at the Monday, April 23rd, meeting, 8:00 p.m. in the Lone Star Gas Company auditorium.

Geneva, Ill.: Dr. Gilbert Raash, of the Illinois Geological Survey, will speak at the meeting of the Fox Valley Astronomical Society on April 3rd in the Geneva City Hall. On April 21st, the society will hold its annual banquet, also in the City Hall, when Dr. Thornton Page, of the University of Chicago, will lecture on "Cosmic Abundances."

Greensboro, N. C.: At the April 11th meeting of the Greensboro Astronomy Club, in the science building of the Woman's College at 8 o'clock, J. P. Molen, U. S. Weather Bureau, will speak on "Meteorology, the Step-child of Astronomy."

Indianapolis, Ind.: The Indiana Astronomical Society will meet on Sunday, April 1st, at the Riley Library, 2:30 p.m. The lecture by Dr. Harry E. Crull, of Butler University, on "Wonders of Our Milky Way," will be given at this meeting, instead of in March, as was announced last month.

Kalamazoo, Mich.: The Kalamazoo Amateur Astronomical Association will meet on Saturday, April 28th, in Vicksburg, Mich., at the home of Mr. and Mrs. Spencer Van Valkenburgh, at 8 o'clock. Max Kester will speak on "Naked-eye Astronomy."

Madison, Wis.: "Observatories and Telescopes" will be the subject discussed by Dr. C. M. Huffer, of Washburn Observatory, speaking at the April 11th meeting of the Madison Astronomical Society, 8:00 p.m. at the observatory.

Minneapolis, Minn.: On Wednesday, April 4th, at the meeting of the Minneapolis Astronomy Club, 7:30 p.m. in the Library Science Museum, Paul Soderlund, of Northwest Airlines, will speak on "Weather Problems of an Airline Pilot." On April 13th, Friday, the society will have a field trip to Carleton College.

New York, N. Y.: "The Atoms in the Sun" will be discussed by Dr. Edward L. Fireman, Brookhaven National Laboratory, at the April 4th meeting of the Amateur Astronomers Association, 8 o'clock, American Museum of Natural History.

Rutherford, N. J.: Astronomical literature and records, past and present, will be discussed at the April 5th meeting of the Astronomical Society of Rutherford, held at the Y.M.C.A. at 8 o'clock.

Washington, D. C.: The National Capital Astronomers, at its meeting on Saturday, April 7th, 8:15 p.m. in the Commerce Building auditorium, will hear Dr. E. A. Le Lacheur, of the Coast and Geodetic Survey, speak on "Tides."

THE OCCULTATION OF VENUS

EXCEPT for part of the Northeast, the occultation or close conjunction of Venus and the moon appears to have been well observed. The front-cover photograph was made at the Goethe Link Observatory at Brooklyn, Ind., shortly after the moon had occulted Venus. Dr. Frank K. Edmondson writes that operating the 10-inch asteroid camera was definitely a three-person job: "Mary Connelley was the timekeeper, checked the clock against the radio, and made all entries in the record book. Richard Nicholas loaded plateholders and kept feeding them to me, and I was on top of a ladder making the exposures. We took about a dozen pictures altogether, with widely varying exposure times (front-cover exposure 10 seconds)."

The pair of pictures below is part of a series taken with the 12-inch f/15 Kirkwood Observatory refractor at Bloomington, Ind., by Arnold Klemola, Kenneth Hallam, and Dr. James Cuffey, of the University of Indiana. The exposure was ½ second, on Panatomic-X film with a yellow filter. Not suitable for reproduction was the first picture in the series, showing Venus just half immersed behind the dark limb of the moon.

At Vicksburg, Miss., Mrs. Albert M. Bonelli enjoyed the celestial picture with the only clear evening horizon this year. From an eminence overlooking the Mississippi River, she watched Venus and the moon until they set.

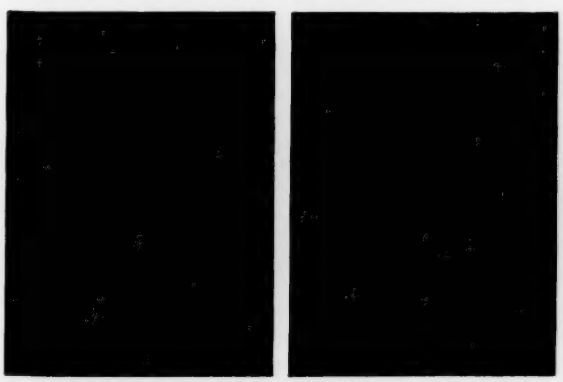
At Milwaukee, Wis., the occultation caused some excitement, for although Herbert W. Cornell had told the Milwaukee **Journal** about it in advance the newspaper did not print anything, "perhaps because we had been having such wretched weather," writes Mr. Cornell. "Then, for a change, we had a clear western horizon and both newspapers, the **Journal** and the **Sentinel,** were flooded with phone calls as to 'what is happening to the moon?' We were called up in a hurry to explain all about it, and both papers published pictures that their staff photographers took. Of course, by the time they got their cameras in action, there was a separation of four or five minutes of arc between the planet and the moon's limb."

At Dallas, Tex., the **Daily Times-Herald** sent a photographer out to the observing party at the home of E. M. Brewer, president of the Dallas Astronomical Society. Mr. Brewer had already given the city's largest papers information for stories that were run in advance of the event. "I thought from the diagram in the January issue of **Sky and Telescope,"** states Mr. Brewer, "that we would have an occultation of possibly 15 or 20 minutes, but it was just a grazing contact, as best as I could judge. We had beautiful weather, and observed with a 10-inch and two 6-inch reflectors."

Paul W. Stevens, of Rochester, N. Y., describes his experiences: "We hoped a cold front passage might bring clearing skies; it did, about an hour before sunset—just breaks in the clouds, not a real clear sky. After sunset a bank of clouds still hovered over the city, but to the south the skies looked promising. Remembering what a difference the 35 miles between Wolseley and Bredenbury made in 1945, I made sure that my expedition was mobile. About eight miles south of the center of Rochester, in the village of Henrietta, I had good views of the immersion and emersion between low clouds.

"Immersion came 33 minutes after sunset, so that the three planets were visible to the unaided eye against a rather bright twilight. Venus could be detected without optical aid as soon as emersion started. Mars and Jupiter attracted much attention a quarter of a degree apart. The clouds completely closed in again and snow started, 10 minutes after emersion!"

William R. Hunter, at Panama City, Fla., took this picture at 6:00 p.m. local time. Note the separation of Venus and the moon. Mars and Jupiter also show. Exposure 10 seconds at f/2 on Panatomic-X film, with a Clarus 35-mm. camera.



Venus emerging from behind the moon (left), and the same scene a short time later. North is at the top. Indiana University photographs.

PALOMAR DIRECTOR TO SPEAK

In connection with the annual meeting of the National Academy of Sciences, a public lecture will be given on Monday evening, April 23rd, at 8 o'clock in the auditorium of the academy building, 2101 Constitution Ave. N. W. Dr. Ira S. Bowen, director of Mount Wilson and Palomar Observatories, will give an address entitled, "Palomar Observatory."

NEW CLUB IN PENSACOLA

Down here in Pensacola, Fla., we are trying to keep going our newly formed amateur astronomy club. We are quite far removed from any science group, observatory, or planetarium. Meetings are held once a month at my house, at which time I show movies or give talks on astronomy. The Naval Air Station has been very co-operative in providing films on various phases of science, including astronomy and atomic energy.

After our meetings, we adjourn to my back yard, where we observe with 6-inch and 10-inch reflectors that I made while a member of the Minneapolis Astronomy club.

If our club continues to function as it has in the past, we hope to apply for membership in the Astronomical League.

HAROLD YESNES
305 Kalash Rd. S.E.
Warrington, Fla.

H. LEROY BENFER DIES

On December 22nd, H. Leroy Benfer, chairman of the instruments section of the National Capital Astronomers, died. He conducted an optical coating laboratory near Washington, although he had originally been a radio operator on the Grace Lines. In 1937, the Hayden Planetarium's eclipse expedition to Peru traveled on his ship, and Mr. Benfer found the opportunity to expand his interest in astronomy. He joined the Amateur Astronomers Association in New York City, and moved to Washington, D. C., in 1941, where he became active in both amateur and professional optics.

NEWS NOTES

By Dorrit Hoffleit

CATALOGUE OF COMETS

The French almanac for 1950 (*l'Annuaire du Bureau des Longitudes*) contained a general list of all known comets discovered up to the end of 1948. This list has now been reprinted as a separate pamphlet of 86 pages and should be most welcome to anyone dealing with the statistics or history of cometary apparitions. It was printed in Paris by Gauthier-Villars, 55 Quai des Grands-Augustins.

Prepared by M. F. Baldet, the present work is an extension of a similar list published by Bigourdan in 1927. A total of 1,619 comet appearances are catalogued, 293 of which are discoveries of the past 50 years. There are 207 returns of 39 periodic comets, and thus 1,412 different objects are listed. Orbits have been determined for 738 comets. A few of the very early records taken from Oriental sources are noted as possibly describing novae rather than comets.

A bibliography of the sources used in compiling the catalogue is included.

HIGH OBSERVATORY IN BOLIVIA

In a letter to *Sky and Telescope*, Ismael Escobar V., director of meteorology at the University of La Paz, Bolivia (at present at Massachusetts Institute of Technology), points out that the article on high-altitude laboratories by S. A. Korff in *Physics Today* (see News Notes in February) failed to mention the Chacaltaya Observatory. This station is located at an altitude of 17,700 feet, over 3,500 feet higher than the highest of the permanent cosmic ray stations cited by Dr. Korff.

Located at latitude 16° 19′ south, longitude 68° 10′ west, the Chacaltaya Observatory is within 1½ hours driving time of La Paz, and is accessible by road the year around. It has been in operation as a meteorological observatory since 1943, and since 1947 physicists have also been using it for cosmic ray observations. Under a joint arrangement of the university and the Bolivian weather bureau, a new building and power facilities are to be completed this year. "At that time," writes Dr. Escobar, "scientists, including astronomers, are welcome to work there."

The new Chacaltaya Observatory building is 5,280 meters above sea level.

Another South American observatory has been added to Dr. Korff's list. In the February *Physics Today*, he describes the Institute of Andean Biology, devoted primarily to a study of physiological effects of high altitudes, located 14,900 feet high at Morococka, Peru, and including a laboratory with full power facilities.

IMMACULATE SUN

The AAVSO Solar Division assiduously watches the sun and keeps tabs on its appearance. On December 19, 1950, not a single spot was detected. This had not happened since September 15, 1945, an interval of more than five years. The event marked the beginning of the current sunspot minimum, and new spots were expected to appear soon at higher latitudes on the sun.

A MYSTERY SOLVED

In January, 1948, an Air Force pilot, sighting a "flying saucer," climbed to an altitude of 30,000 feet in a fatal attempt to follow and identify the mysterious object. Now, three years later, *Look* magazine has been authorized to publish the explanation given by Dr. Urner Liddell, chief of the nuclear physics branch of the Office of Naval Research.

The pilot was chasing a huge balloon known as the *Skyhook*. It has a diameter of 100 feet, attains speeds in atmospheric currents up to 200 miles an hour, and can reach heights up to 19 miles. It carries delicate meteorological and nuclear physics instruments for studying the properties of the very rarefied upper atmosphere. No ordinary aircraft can reach comparable heights. Concerning flying saucers, Dr. Liddell said, "There is not a single reliable report of an observance which is not contributable to the cosmic balloon."

H. B. RUMRILL DIES

A well-known amateur astronomer and observer of the sun, Harry B. Rumrill, died at his home in Berwyn, Pa., on January 23rd. He was a past president of the Rittenhouse Astronomical Society, and had built his own observatory.

IN THE CURRENT JOURNALS

ASTRONOMY, by Otto Struve, **Journal** of the Franklin Institute, January, 1951, 125th anniversary issue. "In order to learn what the astronomers of today believe may happen in their spheres of interest during the next few years, I mailed a circular letter to a number of well-qualified astronomers and asked them to send me their ideas concerning 'the things to come.'" The article gives the composite predictions of 55 astronomers.

ROCKET NAVIGATION, by Samuel Herrick, **Navigation**, December, 1950. "There are many fascinating problems that the prospect of rocket voyages has brought for the first time to the attention of astronomers interested in celestial mechanics. . . . It remains for the engineer, the chemist, the aerodynamicist, and several categories of physicists to set the date."

A RESUME OF RESEARCHES AT THE ARIZONA METEORITE CRATER, by H. H. Nininger, **Scientific Monthly**, February, 1951. "It has been almost sixty years since the attention of scientists was first called to the strange topographical feature now known variously as Meteor Crater, the Arizona Meteorite Crater, and Barringer Crater. . . . Without doubt cosmic impact is a process that must find a more prominent place in future geological theory."

CLUSTERS OF GALAXIES

Although all the individual galaxies comprising a cluster of galaxies are not of the same mass and probably do not behave precisely as would the molecules in a globular volume of gas containing only identical particles (such a volume is known as an Emden sphere), yet a fairly good approximation of conditions in such clusters can be attained by these simplifying assumptions. Dr. Fritz Zwicky, of Mount Wilson and Palomar Observatories, finds that the observed numbers of galaxies out to various apparent distances from the center of the Cancer cluster are proportional to the numbers of molecules at a corresponding distance from the center of an Emden sphere. The comparison leads to an estimate of 560,000 galaxies per cubic megaparsec as the central density of the cluster. In the *Publications* of the Astronomical Society of the Pacific, Dr. Zwicky remarks that at the centers of large clusters the individual galaxies literally touch one another.

Inasmuch as the structure of a galaxy depends on the velocities of its members as well as on its density, a comparison of the velocities in two clusters may be made when their structure is determined by the above assumptions. Thus, knowing that the velocity dispersion in the Coma cluster is 840 kilometers per second, Dr. Zwicky predicts that in the Cancer cluster it should be 486 kilometers per second.

Finally, he comments, "A comparison

of the structural indices of near-by and of very distant clusters promises to render decisive evidence for or against the short time scale which is postulated by the advocates of an expanding universe."

PATRONS OF ASTRONOMY

Within one month, two patrons of astronomy, both members of the Harvard Observatory visiting committee, died: A. Cressy Morrison at the age of 86, on January 9th, and George Russell Agassiz, 89 years old, on February 5th.

Mr. Agassiz, a zoologist, was a member of a distinguished family of naturalists, scientists, and educators. He gave Harvard Observatory a stone cottage for recreational purposes at its Massachusetts observing station. He was a member of the Harvard University board of overseers, a fellow of the American Academy of Sciences, and a member of the Massachusetts Historical Society.

Mr. Morrison, a chemist and former executive of the Union Carbide and Carbon Corporation of New York, had discovered a method for separating oxygen and nitrogen in a magnetic field. He was the author of *Man in a Chemical World* (1937). He had been working on the relation between scientific and religious thought when Julian Huxley's *Man Stands Alone* appeared. In retaliation, Morrison called his own book *Man Does Not Stand Alone* (1944). The A. Cressy Morrison prize is well known in astronomy. He was a fellow of the New York Academy of Sciences, a member and onetime director of the Amateur Astronomers Association, and chairman of the committee on astronomy and the Planetarium of the American Museum of Natural History.

TERMINOLOGY TALKS.

J. Hugh Pruett

Rotation, Revolution

We should distinguish between two terms which are sometimes used synonymously. Astronomically speaking, however, rotation refers to the turning of a body on its own axis; revolution, to the movement of one body around another. Thus, the earth rotates once a day, and revolves around the sun once a year.

If from out in space we could look down upon the north poles of the sun, the planets, and the planetary satellites, we would see that both the rotations and revolutions of most of them were in a general counterclockwise direction.

Moon Rotation

A very simple experiment will prove helpful in the understanding of the moon's rotation and other phenomena. In the center of a sheet of paper lay a 50-cent piece. This represents the earth. Around this and at some distance from it draw a circle to represent the nearly circular orbit of the moon. At the top of the circle, to represent the moon (not to scale) lay a dime "heads up" and turn it so the face on it is looking toward the earth-coin.

It is well known that in general one side of the moon is always facing the earth. Now move the moon-coin along its orbit in a counterclockwise direction and at the same time rotate it a little, also counterclockwise, so as to keep it constantly facing the central earth-coin. (Some illustrate this celestial motion by walking around and constantly facing a chair.)

How many times has the dime rotated while making one complete revolution around the 50-cent piece and always facing it? I have heard people say that since the moon constantly faces the earth it does not rotate at all. Careful consideration and study of the motions of the moon-coin in this experiment will convince the inquirer that it has made one complete rotation, but there has been no change of facing toward the center. The score is then: revolution, one; rotation, one; change of facing, none.

Kinds of Months

Our term *month* is definitely derived from *moon*. The least scientific, at least the month most "unmoonlike," is the *solar* month, 1/12 of an ordinary year, or about 30½ days in average length. This might be designated the approximate business month.

The *sidereal* month represents the true revolution period of the moon around the earth, the term clearly referring to the stars. For observers on the earth, the sidereal month is the time required for the moon to move from conjunction with a certain star entirely around the celestial sphere and back to that star again. This interval averages $27^d\ 7^h\ 43^m\ 11^s.5$, or approximately 27 1/3 days; but there may be a variation in its length by as much as seven hours.

The *synodic* month likely seems the most reasonable to those who diligently observe the varying phases of our lunar neighbor. The word comes from *synod*, which refers to a meeting, and astronomically refers to a conjunction, or the seeming "meeting," of the moon and the sun. A synodic month is, then, the time from one new moon until the next. Its average length is $29^d\ 12^h\ 44^m\ 2^s.8$, or approximately 29½ days. There may be a variation in this period by as much as 13 hours.

Why the time from new moon to new moon is longer than the revolution period of the moon is shown in the diagram. When the moon is in the position *N* it is new. As the earth and the moon together revolve around the sun, the moon continues to encircle the earth in a counterclockwise sense. After one complete revolution of the moon (sidereal month) it gets to position *S*, and to earth dwellers is again aligned with the same star as when in position *N*. But about two days more are required for the moon to get to position *N'*, where it will again be aligned with the sun and be at the new phase, thus completing a synodic month.

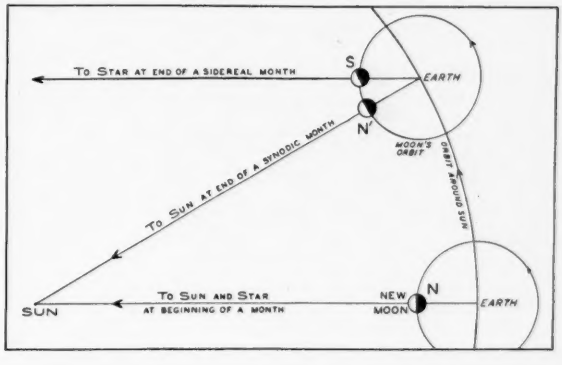
As for an observer located on the moon itself, a lunar day would not be completed until the moon had again reached the position at *N'*. Thus, the lunar day has the same length as the synodic month, that is, it keeps step with the moon's phases.

The *anomalistic* month is the average time required for the moon to revolve from the point in its orbit nearest earth (perigee) back to that point again. Its length is $27^d\ 13^h\ 18^m\ 33^s.1$.

The *nodical* or *draconic* month is the mean time required for successive returns of the moon to the ascending node of its orbit, $27^d\ 5^h\ 5^m\ 35^s.8$.

The *tropical* month is the mean time required for the moon to pass from one point of the ecliptic back to that point again. It differs from the sidereal month by only 6.8 seconds, and is $27^d\ 7^h\ 43^m\ 4^s.7$ long.

The above values for the lengths of the month are given in the *American Ephemeris and Nautical Almanac*, where they are credited to E. W. Brown.



This diagram shows that the length of the sidereal month is considerably less than that of the synodic month.

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BOOKS AND THE SKY

QUAKERS IN SCIENCE AND INDUSTRY

Arthur Raistrick. Philosophical Library, New York, 1950. 349 pages. $6.00.

ALTHOUGH this book will be of greatest value to Quakers, it does contain much material to interest astronomers and other scientists. It is written by one who obviously knows both Quaker history and the history of science. He has been president of the Friends Historical Association in London, and for 20 years lecturer in applied geology at King's College, Durham University. He is considered one of the outstanding authorities on the history and geology of the North of England.

The first two sections of the book deal with the early history of the Society of Friends (founded in 1647), and with its influence on industrial England in the 17th and 18th centuries. The author shows how their peculiar beliefs and the severe persecutions which they suffered determined the nature of the trades and industries which they entered. Their refusal to take an oath (as implying a double standard of truth) and to conform to the rites of the established church excluded them from the universities, trade guilds, professions, and from politics. Their testimony against slavery and war closed all military professions and certain trades to them.

In the search for the "innocent trades," many Quakers became ironmasters and established a national basic industry making commonplace articles such as kettles, frying pans, nails. The author states, "Minds which in the universities would have provided the research workers and scholars, were diverted into business, and found their most congenial outlet in the more technical businesses, where an aptitude for study could find expression in experiment and observation." The result of their constant concern for education was that the whole Society was literate and accustomed to reading and study. The book follows Quaker enterprise through trade and commerce, mining and iron smelting, textiles and banking, in each of which important and original contributions were made. The Friends prepared some of the way for the industrial revolution, not only in the spheres of technology and finance, but in their attitude toward business. The desire for wealth for its own sake was considered as sin, and the Quakers regarded trade and industry as a service to the community. They insisted on a fixed price for goods, and maintained a fundamental belief in equality and brotherhood, which led to better employer-employee relationships.

The third section, "Quakers in Science and Medicine," mentions Friends prominent in botany, geology, and medicine. " . . . the scientist and the Quaker share the insistence on the complete surrender to the guidance of truth."

The chapter of interest to astronomers is entitled, "The Problem of Time: Clock and Instrument Makers." The first generation of Friends was contemporary with Newton. Thomas Tompion made clocks for the Greenwich Observatory at the time of Flamsteed. Daniel Quare developed many refinements for clocks, and made a watch for William III which shows phases of the moon, sundial time, and the course of the sun. His refusal to take the oath led him to decline the invitation to be the king's watchmaker. George Witchell, "excellent astronomer," is briefly mentioned. George Graham improved the clock, invented the mercurial pendulum, and made the mural arc at Greenwich and the transit instrument sent north by the French Academy to determine the true figure of the earth. He also made the first high-quality zenith sector, and constructed many instruments for Bradley, including the zenith sector with which he discovered aberration and nutation. He made the planetarium for Lord Orrery, from which other "orreries" derive their name. Samuel Frotheringham was a distinguished mathematician who made a clock with two minute hands, one to tell true time and the other apparent

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time. "The calculations for such a clock were of no mean order." Jeremiah Dixon went on three expeditions to view transits of Venus, one to the Cape of Good Hope with Maskelyne and Charles Mason, assistant observer at the Greenwich Observatory. He and Mason later teamed up to lay out the Mason-Dixon line between Maryland and Pennsylvania.

In the author's words, " . . . it is true to say that Quakers were decidedly involved in the contributions made to safer navigation and to astronomical observations at the beginning of the eighteenth century."

MARJORIE WILLIAMS
Smith College Observatory

SOME FAMOUS STARS

W. M. Smart. Longmans, Green and Co., New York and London, 1950. 219 pages. $2.50; 15s.

THE WAY to get a scientist to talk and write on a broader front than his immediate researches is to invite him to give and later print a well-endowed series of lectures. In many instances, the only longer writings we have of top-flight men are found in such volumes. Well-known examples are the **Stellar Motions** of W. W. Campbell, de Sitter's **Kosmos,** and in 1936 that minor classic, **The Realm of the Nebulae,** by E. P. Hubble. More recently there have been the important 1947 Tarner lectures by Sir Edmund Whittaker, **From Euclid to Eddington,** and **Stellar Evolution,** by Otto Struve. The latest book along these lines is that by W. M. Smart, who is considered by many to be second in stature only to the Astronomer Royal in British astronomy.

In **Some Famous Stars,** Professor Smart, current president of the Royal Astronomical Society, prints eight lectures fitted to a rather popular level. Their special merit lies in the neat choice of subject matter so that he is able, without getting beyond thin backgrounds, to give full and lucid discussions of such things as the mass-luminosity relation, which is often merely touched on in many college textbooks that are far heavier reading. Years of effective teaching are reflected in the gentle but effective way the often formidable Russell-Hertzsprung diagram is introduced.

Each of us has our entry for a stellar hall of fame, so it must be explained that the author uses special stars to illustrate the methods of attack on certain problems, but the book still contains stars that would have to be on any such list. The chapter headings are: Introduction; 61 Cygni, The First Measurement of the Distance of a Star; The Companion of Sirius; Algol, the Demon Star; Epsilon Aurigae, a Giant Star; Delta Cephei, a Pulsating Star; Exploding Stars; Delta Orionis and the Interstellar Cloud.

It was not his father Alvan Clark, as stated in the book, but Alvan G. Clark, who discovered Sirius B with an 18½-inch lens (not a 20-inch). Of more interest than such minutiae is the diagram on page 61 showing the Big Dipper (known in England as the Plough) some 25,000 years ago and not "at present."

Astronomy would be a far more popular subject if tradition allowed the use of books like this one for texts. In any case, here is a pleasant guide for amateur astronomers who wish to know what all the shooting is about up on the astrophysical frontier.

It is a pleasure, too, to find included the anecdote of Sir David Gill's use of an analogy involving the angle subtended by a threepenny piece at 12 miles. The chairman, at the conclusion of the lecture, said that the thing that impressed him most was the anxiety of his Scottish friend about a thru'penny bit a dozen miles away!

JOHN W. STREETER
Fels Planetarium

PHYSICS OF THE SUN AND STARS

W. H. McCrea. Hutchinson's University Library, Hutchinson House, London, W. 1, England, 1950. 192 pages. 7s 6d.

THIS modest but comprehensive little book may be described as a primer of astrophysics. The author approaches the subject in a manner "neither historical nor technical," but he does not avoid difficult concepts, nor conceal from the reader the complexity of the subject.

Astrophysics, properly understood, employs the principles of physics to analyze the behavior of matter throughout the cosmos. Its tremendous attraction lies in the almost incredible variety of conditions within the cosmic span. The astrophysicist is concerned with the interaction of matter and radiation, the properties of the atomic nucleus, the electrons that surround the nucleus, and the constituents of dissociated atoms and molecules. He is equally concerned with the statistical properties of assemblies of these particles, as embodied in the laws of gases. Principles drawn from terrestrial physics must be applied under conditions inaccessible in the laboratory.

Dr. McCrea defines, in simple and comprehensible terms, the physical principles that are used to analyze the behavior of sun and stars. Though he omits all mathematical developments, he does not avoid formulae in stating the conclusions of theory. The result is a book that will give the layman a clear idea of the scope of astrophysics without requiring him to master its technique. The chapter on stellar constitution will seem hard reading for the beginner, but it will afford an insight into a subject usually available only in advanced textbooks.

CECILIA PAYNE-GAPOSCHKIN
Harvard College Observatory

NEW BOOKS RECEIVED

WELTSYSTEM, WELTAETHER UND DIE RELATIVITAETSTHEORIE, *Karl Jellinek,* 1949, *Wepf & Co.,* Basel, Switzerland. 450 pages. 45 SFr.

The theory of relativity and cosmology, in an exposition intended particularly for experimental scientists with no special knowledge of theoretical physics. The author makes extensive use of the ideas of a universal ether and a universal co-ordinate system, relative to which the average velocity of the galaxies is zero. By appealing to these concepts, he resolves a number of the well-known paradoxes of relativity. The book, in German, assumes that the reader has had a first course in calculus.

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How to Build a Quartz Monochromator — I

By Richard B. Dunn, *Harvard Observatory*

Since the prominences on the sun were first observed during solar eclipses, astronomers have tried to explain their many different shapes, their activity, and their apparent defiance of the solar gravitational field. They present ever-changing phenomena — no two prominences are exactly alike (Fig. 1). In this respect, the sun presents a daytime show as contrasted with the usual night showing of the stars. The **really** active amateur could observe the sun during the day, the stars at night, and build instruments when the weather is cloudy!

Amateur astronomers, who have hitherto confined their solar observing chiefly to sunspots and other features of the photosphere, should now take advantage of the fact that in the past few years a powerful new instrument has been developed for prominence observing. Formally known as the quartz interference polarizing monochromator, it is essentially a complex filter that isolates a very narrow band of the spectrum and that has a wide field of view. It makes possible observing the sun in the light of the red hydrogen-alpha line in its spectrum or, if preferred, in some other wave length.

Essentially, the problem consists of eliminating the light scattered by the earth's atmosphere; this light makes the sky around the sun appear brighter than the prominences themselves. Perhaps the easiest way to avoid this scattered light is to go to view a total solar eclipse, but eclipses are few and far between and afford only a few minutes of observation in each case.

Why not create an artificial eclipse inside the telescope by putting an opaque disk at the focus of the objective? This does not work in practice unless the instrument is highly refined. It was not until comparatively recently that Lyot in France finally perfected a coronagraph that "created" an eclipse; under ideal conditions the prominences and even the inner corona of the sun can be seen.

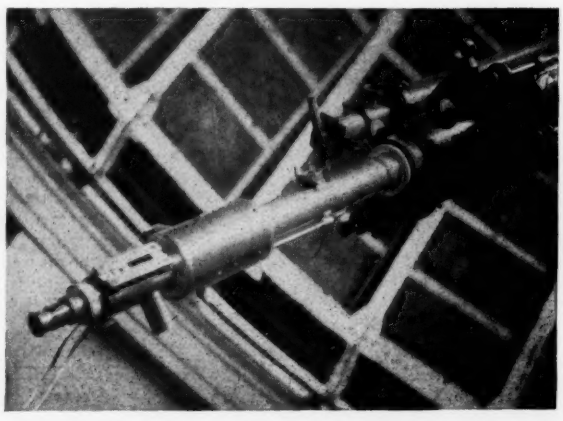
Threescore years ago, however, the spectroheliograph was invented, by the simple expedient of employing a second slit in a spectrograph to isolate a single line of the solar spectrum. At such observatories as Mount Wilson and McMath-Hulbert, instruments of this kind daily scan the sun and record its prominence activity. But a spectroheliograph is complex, and has not proven suitable for amateur experimentation or use. The

Prominences of very different character, photographed by the author through the quartz monochromator.

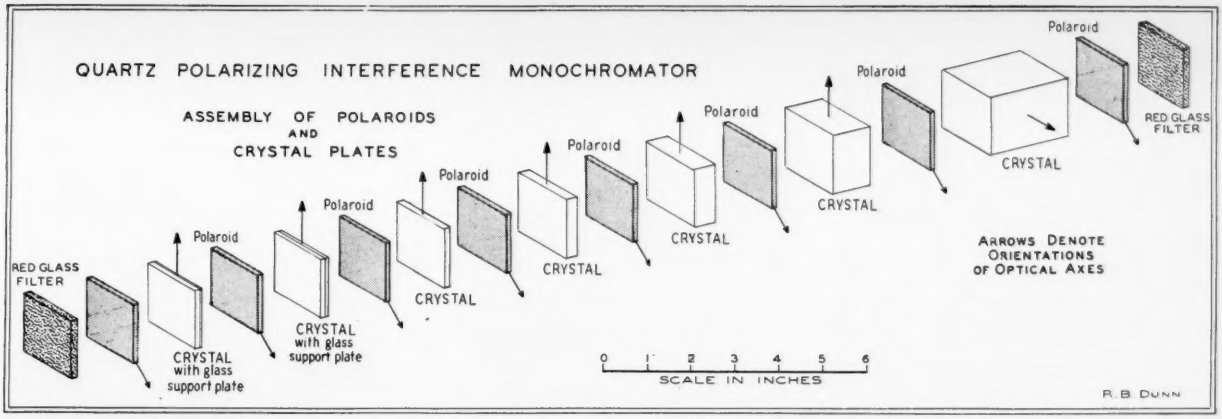
latest development is the monochromator. Both of these instruments act as filters, allowing just the light from a small region of the spectrum to pass to the eyepiece or photographic plate.

When the seeing is at its best and there is some prominence activity, a view through a monochromator leaves nothing to be desired. The chromosphere stands out as a fuzzy layer, separated from the sun's disk by a rather sharp line of demarcation. Every spicule of the chromosphere as well as the streamers of the prominences are easily seen. And the filter works well with average seeing conditions such as prevail most of the time in the eastern United States. Ordinary hand cameras may be used to record the prominences by photography.

The continuous colored background of the solar spectrum is much the same as that given by an incandescent body such as an ordinary light bulb; this light belongs to the sun's photosphere or disk. The dark lines crossing the spectrum are caused by absorption of the light in cooler gases between the photosphere and the observer. These lines belong to the sun's



The quartz monochromator built by Richard B. Dunn, as it appeared when attached to the refracting telescope at the University of Minnesota Observatory.



The quartz blocks and polaroid components of the polarizing interference monochromator. The light may pass through the filter in either direction. Each quartz crystal is half the thickness of the one to the right of it.

reversing layer, the lowest part of its atmosphere, and to the higher chromosphere and prominences. The problem of the filter is to isolate one of these lines.

As may be seen on the back cover of the March **Sky and Telescope,** a few of the lines in the solar spectrum are very strong, and it is in these that the prominences may most easily be observed. There are the Balmer lines of hydrogen, Hα, Hβ, Hγ, and Hδ, and the H and K lines of calcium. (The chromospheric D_3 line of helium is also important for prominence observations; it is not observable on the ordinary disk spectrum). The Hα line is very strong, deep in the red where its light is not scattered by the atmosphere as much as violet light would be, and it is easily photographed with special H-alpha film or with a panchromatic type C emulsion. Finally, the available polaroid sheets work fairly well at the Hα wave length. So far, practically every filter that has been built includes the Hα line, but there is a special set of values by which a filter may be built to work for this line, the D_3 line, and the calcium K line. These values will be discussed later when we design our filter. The Hα line has a wave length of 6562.78 angstroms, the angstrom unit being 10^{-8} centimeter.

The monochromator consists of a series of crystal quartz plates separated by polaroid sheets. Each quartz plate is twice the thickness of its predecessor. It is desirable to have the thickest final crystal possible, for the thicker the quartz plate, the narrower the final transmission band. Although, according to Oehman, a 40-angstrom band (corresponding to 3/8" thickness) should enable one to see the prominences, a narrower band is desirable. The author's filter, which he built at the University of Minnesota, has a thickest element of 1.8", corresponding to a 4½-angstrom band. Some filters in use have bands as narrow as half an angstrom.

The diagram shows a typical setup. A red glass filter is included at the beginning and end of the series of "sandwiches." Note that the quartz is crystal, not fused quartz. The whole filter depends on the optical properties of crystal quartz. There is a special direction in the crystal quartz called the **optical axis,** although it is actually just a direction, not a line as the word axis might imply. Notice that the polaroid sheets are all set with their axes parallel, not crossed to extinction, and the polaroid axes are at 45° to the axes of the crystals.

The polaroid, glass filters, and crystal quartz blocks constitute the optical elements of the filter. In addition, a couple of simple lenses are needed, and all of this is mounted in metal tubing and various small containers for heat controls and the like. The apparatus is all finally assembled as a unit that may be attached to amateur-made telescopes, 6-inch reflectors, 4-inch refractors, and larger. For best results, the telescope should have a focal ratio of f/8 or longer.

If one builds a telescope for the filter, he can use a plano-convex lens. The filter renders the light monochromatic, therefore it is not necessary to correct for achromatism with a two-component objective lens. The polaroid and red filters can be bought ready to use. The quartz need be polished to a flatness of only three or four microns, or about 10 fringes on a 1½" surface, as compared to the usual standard of ¼ wave for flats used as diagonals.

For building the filter, one will need the usual three flat grinding laps used for making flats, a polishing lap, an 8" dia-

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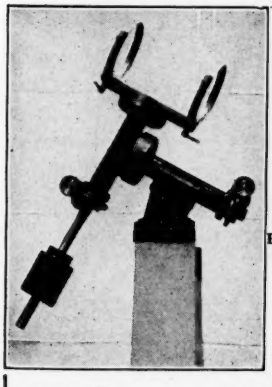

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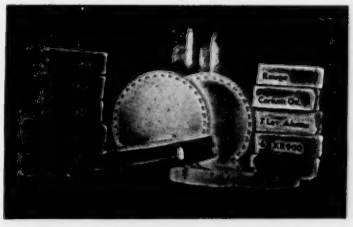

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78 mm (3 1/16")	381 mm (15")	21.00
78 mm* (3 1/16")	451 mm (17¾")	21.00
81 mm (3 3/16")	622 mm (24½")	22.50
83 mm (3¼")	660 mm (26")	28.00
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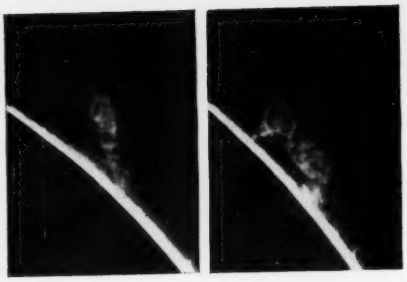

Two pictures of the same prominence, showing changes in 24 hours. The left-hand picture was taken June 11, 1950; the right one the next day. The exposure was 1/25 second on Linograph Pan film.

mond saw, a simple device for locating the optical axis of the quartz, 1" and 2" micrometers, a precision square, a small lathe, and a spectroscope of low resolving power.

The most expensive component of the filter is the quartz. A 1-inch aperture crystal is about 20 dollars a pound, while a 2-inch aperture is 80 dollars a pound. The total expenses of the author's filter were 165 dollars, including 3½ pounds of quartz at 22 dollars a pound, as shown in the accompanying list of out-of-pocket expenses.

The time consumed was on the order of 500 hours, which included making the laps and setting up the diamond saw. Much more time was spent in becoming familiar with equipment, terminology and technique, and in securing materials, than in actual construction.

It is hoped that this series of articles will be detailed enough so that no other references will be necessary for amateur telescope makers, but the following brief bibliography gives some of the papers by original experimenters in the field, and will enable readers to go beyond the scope of these articles. These books and publications should be available in physics and astronomy libraries. All the more recent articles on monochromators are included, and they, in turn, refer to earlier publications.

COST RECORD

Polaroid, 12 3" glass disks (Harry Ross)	$12.00
Red filters (Corning)	3.42
Rimlock diamond saw blade 8", 5/8" arbor, .04" thick	10.80
Quartz (Ward's)	77.76
Water soluble oil for saw, 1 gal.	3.58
Brass and steel for saw fixture	4.20
Rosin and beeswax	1.30
Oil of sweet almond, 1 oz.	.35
Canada balsam, 10 oz.	.90
Glass for plates	2.00
Carborundum	7.00
Cerium oxide polish, 2 lbs.	4.00
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Note: This does not include purchasing a dial indicator, precision square, and the 2" micrometer, or the spectroscope, which may be built or borrowed from a school or college laboratory.

Quartz Monochromator

Evans, John W., **Publications,** Astronomical Society of the Pacific, **52,** 305, 1940.

Evans, John W., **Journal,** Optical Society of America, **39,** 229, 1949.

Lyot, Bernard, **Annales d'Astrophysique, 7,** 31, 1944.

Pettit, Edison, **Publications,** Astronomical Society of the Pacific, **53,** 171, 1941; **54,** 37, 41, 1942.

Spectroheliograph

Hale, George E., **Astrophysical Journal, 71,** 75, 1930.

Ingalls, A. E. (editor), **Amateur Telescope Making Advanced,** Scientific American, 1947.

Working Quartz

Heising, Raymond A., **Quartz Crystals for Electrical Circuits,** Van Nostrand, 1946.

Next month we shall discuss the optical properties of the crystal quartz, as well as problems of its procurement.

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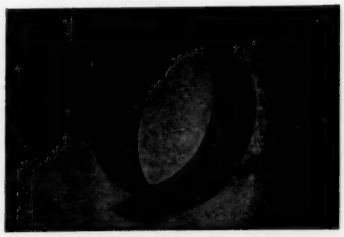

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

VISUAL OBSERVING PROGRAMS FOR AMATEURS — XIII

Variable Star Observing — (continued)

5. Reporting variable star observations. Until you obtain a Julian Day calendar, report your observations in standard time. However, the monthly report form calls for the Julian Day and decimal thereof to express the time of each observation. January 1, 1951, is Julian Day 2,433,648 (beginning at noon), which may be written 3,648 for brevity.

Group all the observations of each star together chronologically, and list stars in numerical order. For instance, all the observations of 021**403** Omicron Ceti should come first, then those of 023133 R Trianguli, and so on.

Reports are sent to AAVSO headquarters, Harvard Observatory, Cambridge 38, Mass., on the monthly report form which the AAVSO provides its members. If you are interested in becoming a member of this society, write to headquarters for an application blank.

6. The use of the variable star observations. Our estimates, say of T Cephei, will be entered in a 10-day ledger, together with all the observations received on that star for the same 10-day period. The average of the observations is considered the brightness of T Cephei for that particular period. Later, a light curve will be drawn, showing brightness plotted vertically against time plotted horizontally. Perhaps the entire history of T Cephei will be studied statistically by some astronomer for its period, shape of light curve, and other correlations.

We cannot discuss in detail here the many types of variable stars, but the new observer does desire some knowledge of the kinds of objects on the AAVSO observing program. The majority are long-period variables that become bright and faint rhythmically, but never do quite the same thing twice. The "variation in the variation" of such a star is perhaps the principal interest at present.

Then there are the SS Cygni stars, which are ordinarily faint but which brighten up quickly occasionally, by several magnitudes, only to fade away again after a few days. Some astronomers consider these stars as repeating novae of small range. The four brightest stars of the R Coronae Borealis type are on the AAVSO lists. These stars are ordinarily bright, but sometimes fade away by perhaps six or eight magnitudes, for months at a time. Novae are immediately added to the AAVSO program when they occur.

During the past year, additions included Luyten's flare star 013**618** in Cetus, the odd star 092720 in Leo, and the sporadic, suddenly brightening variable 203**501** AE Aquarii. And there are the familiar but little understood irregular stars, such as 115158 Z Ursae Majoris and 184**205** R Scuti, which are continually doing the unexpected. There is seldom a week goes by that one or more of the variable stars on an active observer's list does not do something exciting.

Books on variable stars include **The Nature of Variable Stars,** Paul W. Merrill, Macmillan; **Variable Stars,** Gaposchkin and Gaposchkin, Harvard Observatory Monograph; and **The Story of Variable Stars,** Campbell and Jacchia, Blakiston.

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VARIABLE STAR MAXIMA

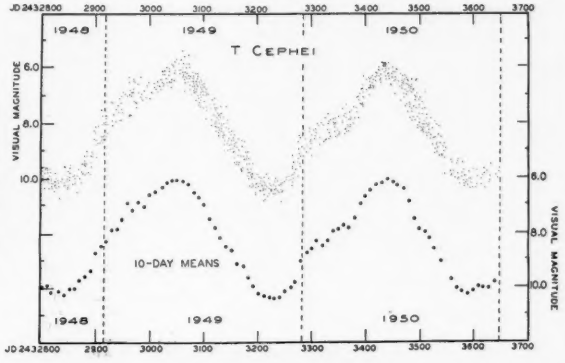
April 3, X Monocerotis, 7.6, 065**208**; 3, R Canum Venaticorum, 7.7, 134440a; 4, R Cancri, 6.8, 081112; 7, T Centauri, 6.1, 133**633**; 8, S Carinae, 5.7, 100**661**; 12, R Virginis, 6.9, 123307; 13, V Cassiopeiae, 7.9, 230759; 16, V Bootis, 7.9, 142539a; 16, RR Sagittarii, 6.6, 194**929**; 23, RT Cygni, 7.4, 194048. May 4, R Andromedae, 7.0, 001838; 6, V Coronae Borealis, 7.4, 154639.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the predicted magnitude, and the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern).

MINIMA OF ALGOL

April 2, 17:50; 5, 14:39; 8, 11:28; 11, 8:18; 14, 5:07; 17, 1:56; 19, 22:45; 22, 19:34; 25, 16:23; 28, 13:12. May 1, 10:01; 4, 6:50; 7, 3:39.

These predictions are geocentric (corrected for the equation of light), based on observations made in 1947. See **Sky and Telescope,** Vol. VII, page 260, August, 1948, for further explanation.



The upper portion of this graph shows the observations of T Cephei reported by individual AAVSO observers. Below is plotted the light curve that results with 10-day means of the same observations.

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COMET NOTES

The first new comet of the year was discovered on February 4th by Miss L. Pajdusakova at the Skalnate Pleso Observatory, Czechoslovakia, in the constellation of Delphinus, moving northeastward. It was of the 9th magnitude. At McDonald Observatory the next day, Dr. G. Van Biesbroeck confirmed the discovery, and since then the new object has been generally observed.

In a highly inclined orbit, 87°, Comet Pajdusakova is rapidly receding from the sun, having passed perihelion late in January, before its discovery. It is expected to be of the 11th magnitude in April. The latest available predictions, by Joseph Brady, Students' Observatory at Berkeley, are:

March	5.0	$23^h\ 17^m.7$	+53°	19′
	15.0	$1^h\ 45^m.8$	+59°	46′

An 11th-magnitude comet was discovered on February 5th by S. Arend and F. Rigaux, Royal Observatory, Uccle, Belgium, in Gemini, moving east and north. According to an orbit computed by Mr. Brady and Nevin Sherman, it had passed perihelion on December 17th, and is rapidly fading in brightness. Its predicted positions are:

March	5.0	$7^h\ 57^m.4$	+31°	58′
	15.0	$8^h\ 13^m.7$	+32°	57′

The only new comet discovered last year, Comet Minkowski 1950a, passed perihelion on January 15th, and is expected to be of the 9th magnitude in March and April. Its ephemeris through April was given in the February issue, page 102. Its northward movement will bring it into very favorable observing position, relatively easy to find in the dark regions of Hydra.

In morning skies this month, periodic Comet Encke, making another return to the sun, should be observable in amateur instruments. Its positions are predicted in the **Handbook** of the British Astronomical Association:

April 4, $22^h\ 56^m.0$, −16° 31′; 14, $22^h\ 51^m.3$, −17° 57′; 24, $22^h\ 53^m.1$, −18° 11′; May 4, $22^h\ 56^m.0$, −18° 13′; 14, $22^h\ 57^m.5$, −18° 23′; 24, $22^h\ 56^m.4$, −18° 50′.

OCCULTATION PREDICTIONS

On the early evening of April 9th, the 3½-day-old moon will pass through the Pleiades, with occultations of q Tauri and 20 Tauri (Maia) predicted to be observable at a few eastern stations. As latitude can make a considerable difference in whether or not a star is occulted by the moon as it moves through the Pleiades, all observers east of the Mississippi River are advised to train telescopes on the moon as soon as it can be picked up before or after sunset. A chart of the Pleiades is on page 309 of the October, 1950, **Sky and Telescope.**

April 9-10 **q Tauri** 4.4, 3:42.3 +24-18.9, 4, Im: **A** 23:19.1 −0.8 −2.0 105; **C** 23:24.3 −0.7 −3.1 124; **E** 23:04.6 −1.6 −3.6 127. Em: **A** 0:23.7 −0.7 −0.4 238; **C** 0:18.9 −1.3 +0.8 219; **E** 23:58.8 −1.8 +2.0 209.

April 9-10 **20 Tauri** 4.0, 3:42.9 +24-13.0, 4, Im: **A** 23:53.1 +0.2 −4.7 142; **B** 23:41.5 −0.3 −3.3 129. Em: **A** 0:26.3 −1.5 +2.0 201.

April 12-13 **49 Aurigae** 5.0, 6:32.1 +28-03.7, 7, Im: **H** 4:00.9 −2.5 +0.6 58. Em: **H** 4:51.8 +0.3 −3.6 336.

April 30-May 1 **Phi Aquarii** 4.4, 23:11.8 −6-18.8, 24, Im: **A** 9:08.5 −0.7 +1.8 69; **C** 8:59.4 −0.6 +1.7 72. Em: **A** 10:16.1 −0.9 +2.0 226; **C** 10:04.9 −0.8 +2.0 225.

For standard stations in the United States and Canada, for stars of magnitude 5.0 or brighter, data from the **American Ephemeris** and the **British Nautical Almanac** are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computations of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo** — **LoS**), and multiply **b** by the difference in latitude (**L** — **LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5, +42°.5	**E**	+91°.0, +40°.0
B	+73°.6, +45°.6	**F**	+98°.0, +31°.0
C	+77°.1, +38°.9	**G**	+114°.0, +50°.9
D	+79°.4, +43°.7	**H**	+120°.0, +36°.0
		I	+123°.1, +49°.5

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.

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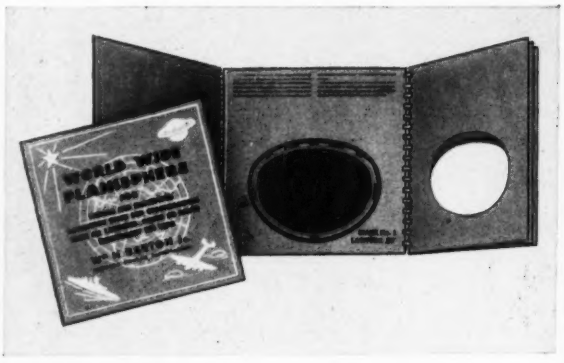

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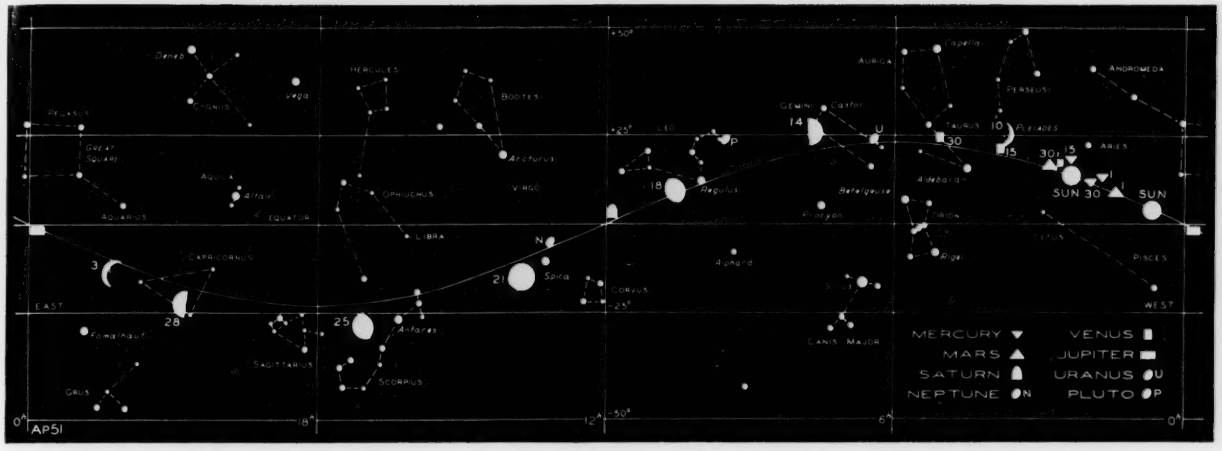

THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown.

Mercury makes its most favorable appearance of the year during the first 10 days of April. Greatest elongation is attained on April 5th, only 19° 12′ east of the sun in longitude. However, the planet will be above the horizon for 1½ hours after sunset and of zero magnitude at elongation. Mercury then rapidly recedes toward the sun, passing it in inferior conjunction on April 25th.

Venus continues as the brilliant evening star in the west, setting three hours after the sun. In a telescope it is only 13″ to 14″ in diameter and gibbous in phase.

Mars, just a few degrees east of the sun, cannot be observed this month.

Jupiter, which passed conjunction in March, is difficult to view as it rises shortly before the sun.

Saturn is in an excellent position for observing, in western Virgo, and of magnitude +0.9. The rings are continuing to close, their inclination to the line of sight being only 1°.6 on April 15th.

Uranus is in the western evening sky, 2° northeast of Mu Geminorum. See the chart in the February issue, page 103, for its position.

Neptune comes to opposition on April 8th, 2,722 million miles from the earth. The chart on page 103, February issue, gives its position. On May 1st, Neptune passes only 4′ south of Theta Virginis.

E. O.

SATURN'S SATELLITES

Information on the configurations of Saturn's satellites for April and May appears below. Refer to the January issue, page 74, for an explanation of the data, and a table giving the periods, magnitudes, and distances of the satellites.

Mimas. April: 8, 3.4; 15, 16.3; 23, 5.3; 30, 18.2. May: 8, 7.1; 15, 20.1; 23, 9.0; 30, 22.0.

Enceladus. April: 9, 6.0; 20, 5.0. May: 1, 4.1; 12, 3.2; 23, 2.3.

Tethys. April: 15, 17.7; 30, 20.1. May: 15, 22.5; 31, 1.0.

Dione. April: 10, 2.3; 21, 1.0. May: 1, 23.6; 12, 22.3; 23, 21.1.

Rhea. April 1, 15.6; 19, 16.9. May 7, 18.4; 25, 20.0.

Titan. April: **E,** 3, 9.6; **I,** 7, 4.1; **W,** 11, 3.8; **S,** 15, 8.3; **E,** 19, 7.3; **I,** 23, 1.9; **W,** 27, 1.6. May: **S,** 1, 6.1; **E,** 5, 5.3; **I,** 8, 23.9; **W,** 12, 23.7; **S,** 17, 4.3; **E,** 21, 3.6; **I,** 24, 22.3; **W,** 28, 22.2.

Iapetus. April: **W,** 9, 1.5; **S,** 29, 5.7. May: **E,** 19, 17.6.

BLUEPRINTS OF THE MOON

EIGHT charts show the moon under various stages of illumination from the thin crescent after new moon to the full phase, and on these charts over 300 lunar features have been conveniently labeled, some of them on more than one chart. Additional blueprints provide an index to these features, by chart number and position.

The blueprints were made by Joseph Lisle Woods and Paul Gwynn Crout from tracings of enlarged prints of photographs taken with the 12-inch reflector at the Northwood Observatory in Baltimore, Md. At normal reading distance, their scale corresponds with a view of the moon magnified about 50 times, and each detail should be visible in a 3-inch telescope, at the proper phase of the moon. Thus, the charts are intended for observers with small refractors and reflectors, and as guides to the vicinities of any of the innumerable details shown on large-scale lunar maps.

Sets of these charts are available for $2.00 each from the Northwood Observatory, 4102 Westview Rd., Baltimore 18, Md.

PHASES OF THE MOON

New moon	April	6, 10:52
First quarter	April	14, 12:55
Full moon	April	21, 21:30
Last quarter	April	28, 12:17
New moon	May	6, 1:35

	April		Distance	Diameter	
Apogee	12,	1h	251,600 mi.	29′	31″
Perigee	23,	23h	225,200 mi.	32′	58″

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SKY PUBLISHING CORPORATION
Harvard College Observatory
Cambridge 38, Mass.

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of April, respectively.

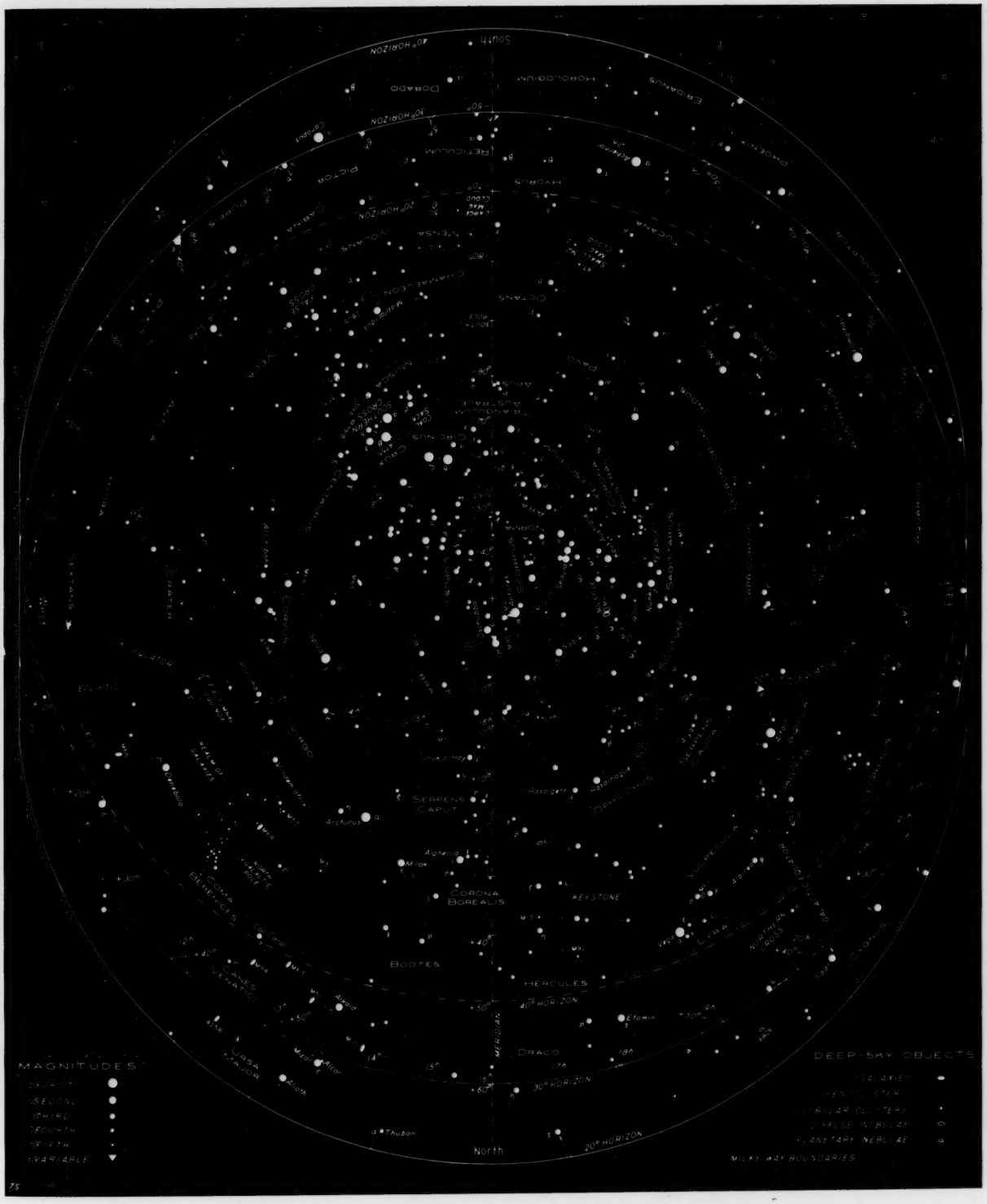
STARS FOR APRIL

WITH two great animals, Leo and Ursa Major, high in the evening sky, northern observers know that spring has come. Regulus, name of the 1st-magnitude star in Leo, means "little king." It is located at the base or end of the handle of the Sickle; above it is η, then γ or Algeiba, ζ or Adhafera, μ or Rasalas, and ϵ, sometimes called Algenubi. Mu and Epsilon together were called Al Ashfar, the Lion's eyebrows, by the Arabs. Following the Sickle, a triangle completes the Lion, with Denebola meaning "lion's tail."

North of the Lion's back is Leo Minor, with the easternmost star on this chart sometimes called Praecipus. The paws of the Bear come down close to Leo Minor; the three pairs of stars set in a line pass overhead for most observers in the United States. The Big Dipper, because of the flattening of the sky, appears much smaller than when it is along the horizon.

The diminishing splendor of Orion in the western sky is being replaced by Bootes and Corona Borealis in the east, heralds of the bright summer skies. Corvus and Virgo can be traced in the southeast, and telescope owners can take increasing advantage of the "realm of galaxies" in the Coma-Virgo region.

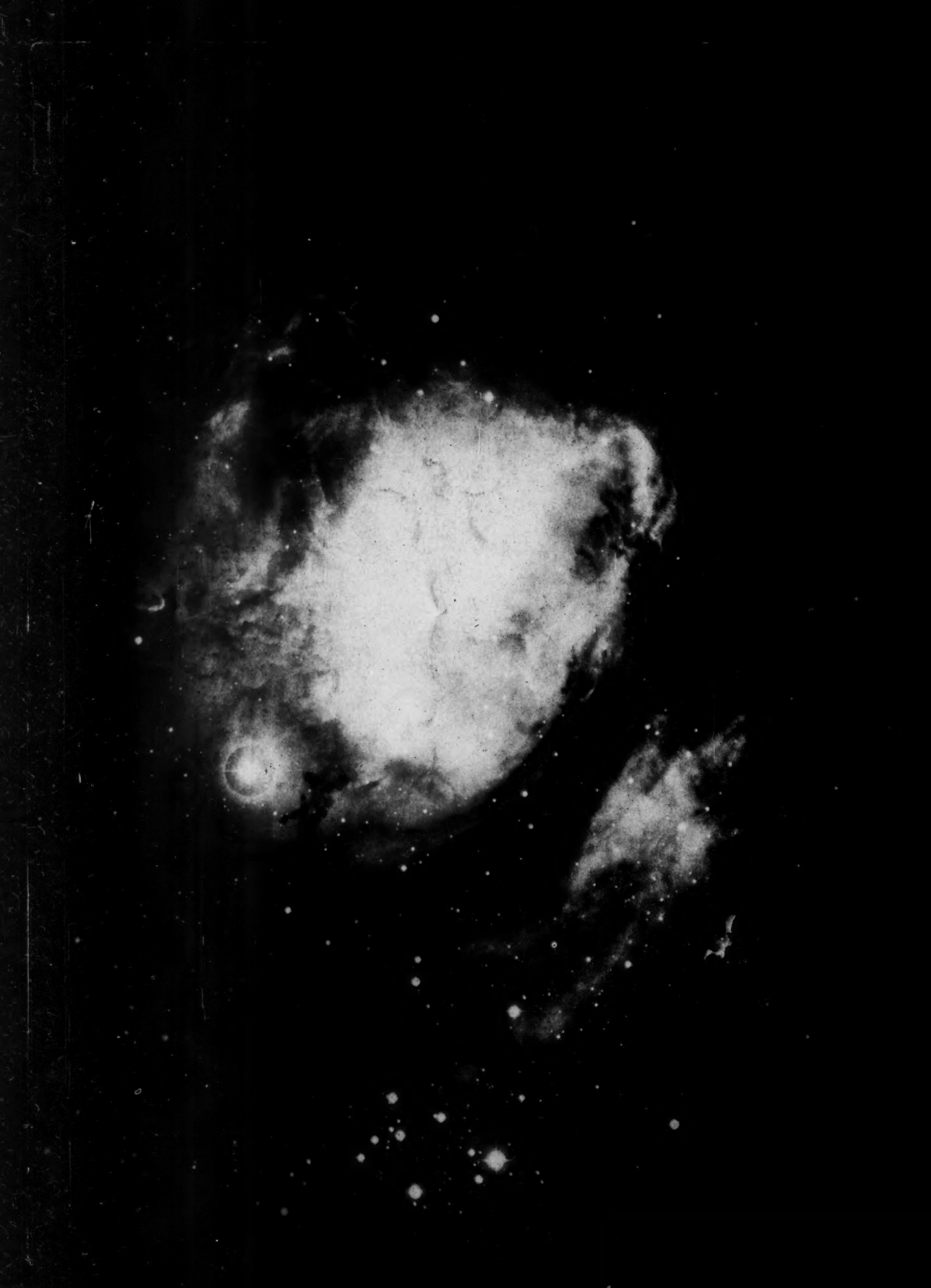
O. G.



The sky as seen from latitudes 20° to 40° south, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of July, respectively.

SOUTHERN STARS

THE bright stars of Centaurus, Crux, Lupus, and Scorpius, ride high overhead for southern observers on July's winter evenings. The closest naked-eye star, Alpha Centauri, is near the meridian. It is a binary star, with each component similar to our sun in size and brightness, as well as in spectral class. It is accompanied by 11th-magnitude Proxima Centauri, about two degrees to the south, recently found to be a flare star.

Near to Alpha is Beta Centauri, intrinsically much brighter but 200 light-years away from us. It lies along a belt of hot **B**-type stars stretching through the four constellations named above. Half of the 40 stars in Scorpius brighter than magnitude 5.0 shown on Klepesta's **Mappa Coelestis Nova** are of spectral type **B.** In Lupus, the percentage is even higher, and the Southern Cross is composed mostly of these bright, hot stars.

By contrast, in the area to the south, including the south pole of the sky and extending from Apus to Indus and Grus on the east, and to Volans and Pictor on the west, only about 14 per cent of the stars brighter than 5th magnitude are of types **O** and **B.** Bright stars are few, and Achernar, of spectrum **B5**, is the only 1st-magnitude star in this area.